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# MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

AD A105293

PEA RIDGE MINE DAM
WASHINGTON COUNTY, MISSOURI
MO 30473

# PHASE 1 INSPECTION REPORT
# NATIONAL DAM SAFETY INSPECTION

**United States Army**
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**St. Louis District**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

SUBJECT: Pea Ridge Mine Dam (MO 30473)

This report presents the results of field inspection and evaluation of the Pea Ridge Mine Dam, Missouri Inventory Number 30473. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: SIGNED 24 DEC 1980
Chief, Engineering Division — Date

APPROVED BY: 30 DEC 1980
Colonel, CE, District Engineer — Date

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# PEA RIDGE MINE DAM

Washington County, Missouri

Missouri Inventory No. 30473

**Phase I Inspection Report**

**National Dam Safety Program**

Prepared by

**Woodward-Clyde Consultants**

Chicago, Illinois

Under Direction of

St Louis District, Corps of Engineers

For

Governor of Missouri

November 1980

## *PREFACE*

*This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.*

*In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.*

*It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.*

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

| | |
|---|---|
| Name of Dam | Pea Ridge Mine Dam |
| State Located | Missouri |
| County Located | Washington |
| Stream | Unnamed Tributary of Mary's Creek |
| Date of Inspection | 24 June 1980 |

The Pea Ridge Mine Dam, Missouri Inventory Number 30473, was inspected by Mr S. F. Gizienski (geotechnical engineer), Mr R. Juyal (hydrologist), and Mr J. B. Stevens (geotechnical engineer).

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. These guidelines are intended to provide for an expeditious identification, based on available data and a visual inspection, of those dams which may pose hazards to human life or property. In view of the limited scope of the study, no assurance can be given that all deficiencies have been identified.

This dam is classified as large due to its 132 ft height. The storage capacity is approximately 10,000 ac-ft. The large dam classification includes dams greater than 100 ft in height or having a storage capacity greater than 50,000 ac-ft.

The St Louis District, Corps of Engineers (SLD), has classified this dam as having a high hazard potential; we concur with this classification. The SLD estimated damage zone length extends approximately 13 mi downstream. The Missouri-Pacific Railroad track and several occupied structures are located within this zone.

The inspection and evaluation indicate that the dam is in generally good condition. In its present configuration, the downstream slope is near incipient failure as its inclination is that of the angle of repose of the cobber reject. However, due to the 110-ft wide crest and present 38-ft elevation difference between the tailings and dam crest, this is not considered a safety hazard. Deemed as a deficiency by the guidelines, is the lack of stability and seepage analyses for the present dam configuration.

No spillway has been constructed for the dam. However, hydrologic/hydraulic studies indicate that the dam will not be overtopped by the 1 percent probability-of-occurrence flood (100 yr flood), or by the Probable Maximum Flood (PMF). The 100 year flood is defined as the flood event which has one chance in 100 of occurring in any one year, or the flood which occurs on the average of once in 100 years. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

As remedial measures for the Pea Ridge Mine Dam, it is recommended that the owner commission a review of the original design (E. D'Appolonia Associates, 1962) in order to re-evaluate, as a minimum, the following topics:

1. Determine the adequacy (or otherwise) of the existing configuration of the downstream slope, including the increased steepness of the slope, but also the increased width of the crest.

2. Make a comparison of the anticipated vs observed seepage rates and draw appropriate conclusions.

3. Make stability analyses, including earthquake effects, for the current and final construction phases.

4. Determine the need for and configuration of a spillway for the final phase of dam construction.

In addition, periodic inspections should be implemented for the dam and appurtenant structures after completion. These inspections should report needed maintenance requirements. Records of the inspections and maintenance should be kept.

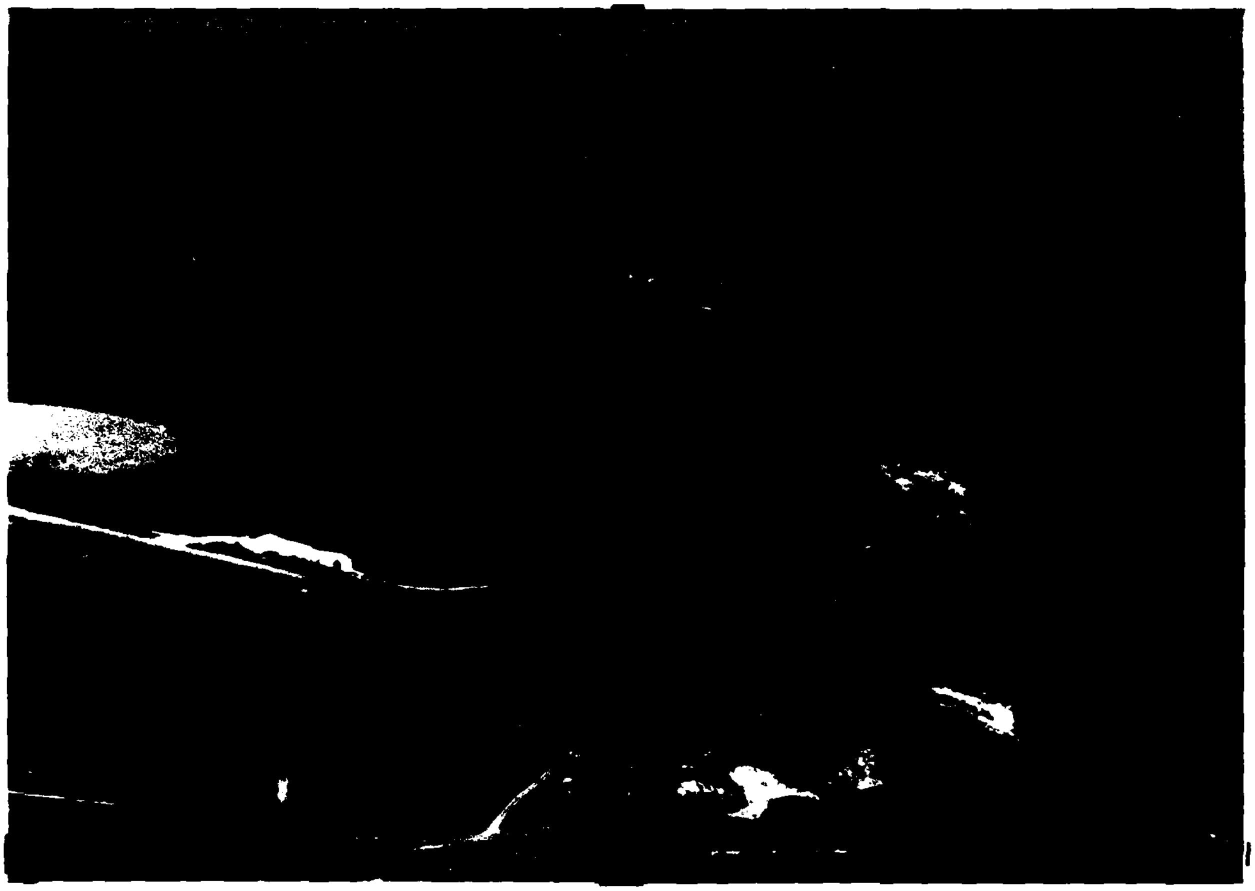
It is suggested that actions on these recommendations be initiated as soon as practical.

WOODWARD-CLYDE CONSULTANTS

Stanley F. Gizienski

Stanley F. Gizienski, PE
Principal

Jean-Yves Perez, PE
Vice President



# OVERVIEW

## PEA RIDGE MINE DAM

MISSOURI INVENTORY NUMBER 30473

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
PEA RIDGE MINE DAM - MISSOURI INVENTORY NO. 30473
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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
PEA RIDGE MINE DAM, MISSOURI INVENTORY NO. 30473

# SECTION 1
# PROJECT INFORMATION

## 1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of Pea Ridge Mine Dam, Missouri Inventory Number 30473.

b. **Purpose of Inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted" (Chapter 3, "Recommended Guidelines for Safety Inspection of Dams").

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams", Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "National Program for Inspection of Non-Federal Dams", prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams" prepared by the St Louis District, Corps of Engineers (SLD). These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations, and private engineers.

## 1.2 Description of Project

a. **Description of dam and appurtenances.** Pea Ridge Mine Dam is an active tailings dam. Unlike most tailings dams in the area which were constructed for barite ore processing operations, this dam was constructed for an iron mining operation.

At the Pea Ridge Mine, a deep iron ore body is being mined. After being hoisted to the surface, the ore is crushed in three stages to a 0.25 to 0.75-in. size. The crushed ore is then passed through a magnetic separator. The non-magnetic portion, known as cobber reject, is then removed from the processing operation. The magnetic portion is further reduced in size and concentrated. From the concentration process, fine tailings are produced which are water-borne and discharged into the impoundment. The fine tailings range from sand to clay in size.

The cobber reject is the primary material used to construct the dam. It is trucked from the plant to the site and dumped on the crest. The cobber reject is then spread over the crest and downstream slope. The method of construction has been the "downstream" method, i.e., as the dam is raised, the dam crest centerline has migrated downstream.

On the upstream slope an impervious blanket from 2 to 8-ft thick is being placed in stages. The purpose of the blanket is to prevent the migration of the fine tailings into the dam. Top elevation of the blanket has been kept at about the reservoir water level.

Beneath the dam are a series of drains. These drains consist of trenches, about 20 ft wide and 10 ft deep, excavated in foundation rock, filled with cobber reject and parallel to the crest (See Fig M24, Appendix C). Water from these trenches is conveyed to the toe drains. As the dam has been raised, new toe drains have been installed and more trenches have been made. The third toe drain was being installed at the time of inspection. Mine rock, a coarser material than the cobber reject, was being used for the toe drain.

There are no spillways or regulating structures at the dam. Inflow is discharged through the relatively pervious dam material and exits at the toe drain. This is generally in accordance with the design.

b. **Location.** The dam is just off Mary's Creek, approximately 11 mi west of Richwoods, Washington County, Missouri, in Sec 4, T39N, R1W. It is about 0.5 mi south of the junction of Missouri Highways 185 and EE, on the USGS Meramec State Park 7.5-minute quadrangle map.

c. **Size classification.** The dam is classified as large due to its 132 ft height. The storage capacity is approximately 10,000 ac-ft. The large dam classification includes dams over 100 ft tall or 50,000 ac-ft storage.

d. **Hazard classification.** The St Louis District, Corps of Engineers (SLD), has classified this dam as having a high hazard potential; we concur with this classification. The SLD estimated damage zone length extends approximately 13 mi downstream. The Missouri-Pacific Railroad track and several occupied structures are located within this zone.

e. **Ownership.** We understand that the dam is owned by St. Joe Lead Co., Clayton, Missouri 63105. Correspondence should be addressed to the Pea Ridge Mining Co., RFD4, Sullivan, Missouri 63080, to the attention of Mr John Schoolcraft.

f. **Purpose of dam.** The dam was constructed to impound fine tailings from iron ore processing.

g. **Design and construction history.** Design of the dam began in 1961 by E. D'Appolonia Associates, Pittsburgh, Pennsylvania (see Appendix C). Construction began in the same year and is currently continuing.

h. **Normal operational procedures.** The normal operational procedure is to discharge the water-borne fine tailings into the reservoir. Water from this and rainfall discharges through the pervious rockfill to the downstream channel. There is no regulation of the pool elevation. Reliance is placed on the 38 ft elevation difference between the dam crest and water level for controlling heavy precipitation runoff from the relatively small drainage area.

## 1.3 Pertinent Data.

a. **Drainage area** — 0.57 $mi^2$

b. **Discharge at damsite.**

| | |
|---|---|
| Maximum known flood at damsite | None observed |
| Warm water outlet at pool elevation | N/A |
| Diversion tunnel low pool outlet at pool elevation | N/A |
| Diversion tunnel outlet at pool elevation | N/A |
| Gated spillway capacity at pool elevation | N/A |
| Gated spillway capacity at maximum pool elevation | N/A |
| Ungated spillway capacity at maximum pool elevation | N/A |
| Total spillway capacity at maximum pool elevation | N/A |

c. **Elevation (ft above MSL).**

| | |
|---|---|
| Top of dam | 908.4 to 912.4 |
| Maximum pool-design surcharge | N/A |
| Full flood control pool | N/A |
| Recreation pool | N/A |
| Spillway crest (gated) | N/A |
| Upstream portal invert diversion tunnel | N/A |
| Downstream portal invert diversion tunnel | N/A |
| Streambed at toe of dam | 776.5 |
| Maximum tailwater | N/A |

d. **Reservoir.**

| | |
|---|---|
| Length of maximum pool | 5000 ft |
| Length of recreation pool | N/A |
| Length of flood control pool | N/A |

e. **Storage (acre-feet).**

| | |
|---|---|
| Recreation pool | N/A |
| Flood control pool | N/A |

| | |
|---|---|
| Design surcharge | N/A |
| Top of dam | 10,000 |

f. **Reservoir surface (acres).**

| | |
|---|---|
| Top of dam | 208 |
| Maximum pool | 208 |
| Flood-control pool | N/A |
| Recreation pool | N/A |
| Spillway crest | N/A |

g. **Dam.**

| | |
|---|---|
| Type | Tailings |
| Length | 1380 ft |
| Height | 132 ft |
| Top width | 110 ft |
| Side slopes | D/S; 1.56(H) to 1(V); U/S, 2.4(H) to 1(V) (in portion exposed to inspection). |
| Zoning | None |
| Impervious core | None |
| Cutoff | Exposed cracks and fissures in foundation filled with clayey residual soil. |
| Grout curtain | None |

h. **Diversion and regulating tunnel.**

| | |
|---|---|
| Type | None |
| Length | N/A |
| Closure | N/A |
| Access | N/A |
| Regulating Facilities | N/A |

i. **Spillway.**

| | |
|---|---|
| Type | None |
| Length of weir | N/A |
| Crest elevation | N/A |
| Gates | N/A |
| U/S channel | N/A |
| D/S channel | N/A |

j. **Regulating outlets.**

None

# SECTION 2
# ENGINEERING DATA

## 2.1 Design

Design documents prepared by E. D'Appolonia Associates, Pittsburgh, Pennsylvania were made available by Mr J. A. Emery, geologist with St Joe Lead Co. These documents are included as Appendix C.

## 2.2 Construction

No formal construction records have been kept. According to Mr Emery, the dam was constructed as designed except that a crest width in excess of 100 ft instead of 20 ft was used, and the downstream slope is steeper than the designed slopes. The dam is considered as being at its final crest elevation and a spillway has not been constructed as originally planned. Mr Emery stated that upon completion of mining operations a study will be made to determine whether a spillway will in fact be required.

## 2.3 Operation

Formal records of the pool elevation or discharge from the dam have not been kept.

## 2.4 Evaluation

a. **Availability.** The only data available for review are the design documents, Appendix C.

b. **Adequacy.** Sufficient data were available to determine a preliminary assessment of the adequacy of the as-built dam. The design report in Appendix C sets forth the basic design being followed for this tailings dam, except the downstream slope presently has an inclination of about 1.5(H) to 1(V) rather than 2.5(H) to 1(V) as shown on the plans. However, the width of the dam crest is in excess of 100 ft as opposed to a design width of 20 ft. Also, the dam has been constructed to its full height providing in excess of 35 ft of embankment height above the water level at the time of inspection. The

embankment section is constructed entirely of hard, broken rock of good shear strength and the present thick section decreases the possibility of a shear failure of such extent as to allow release of the reservoir contents.

Though seepage and stability analyses were made for the dam as designed, analyses for the as-built dam configuration, as per the recommended guidelines, are not on record. These analyses for the anticipated as-built dam sections should be performed by an engineer experienced in the design and construction of dams. Further, such seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. **Validity.** The engineering design data appear to be valid and applicable since the embankment is being built essentially as intended. No studies were made in this Phase I study to compare the actual seepage occurring through the dam against the anticipated seepage. Such studies should be made by the owner before the dam is completed.

## 2.5 Project Geology

The Pea Ridge Mine Dam is located on the northern flank of the Ozark structural dome. The regional dip in the area is toward the northwest. The bedrock exposed at the surface in this area is mapped on the Missouri Geologic Map (1979) as Gasconade Formation (Fig. 4). The Gasconade Formation is typically a light gray-brown cherty dolomite, with a basal sand, the Gunter member. Caves and springs are common in the Gasconade Formation; however, no evidence of solution activity was noted during the visual inspection. The iron ore production is from mineralized basement rock in deep underground workings. The dam embankment is composed of coarse tailings from these underground workings.

The soil in the vicinity of the Pea Ridge Mine is a tan to brown gravelly to silty clay (CL) developed from weathering of the Gasconade Formation. It contains abundant chert fragments and sand. It is mapped on the Missouri General Soils Map (1979) as Hobson-Coulstone-Clarksville Association.

The Anthonies Mill Fault is mapped about 2 mi southwest of the dam. This fault is a short (3 mi long,) northwest-southeast trending fault, probably of Paleozoic age.

The Richwoods Fault zone is located approximately 4 mi northeast of the dam, and has a mapped length of approximately 18 mi. Neither fault is in a seismically active area nor is considered to pose an unusual hazard to the dam.

# SECTION 3
# VISUAL INSPECTION

## 3.1 Findings

a. **General.** Pea Ridge Mine Dam was inspected in the company of Mr J A Emery, geologist with St Joe Lead Co.

b. **Dam.** The dam is composed primarily of hard rock, cobber reject, which ranges in size from 0.25 to 2 in. In addition, rock from mining activities such as shaft excavation and entries to the ore body, called mine rock, has been used. It ranges in size from fine gravel to large cobbles. Mine rock does not comprise a significant portion of the dam.

The exposed portion of the upstream slope is at an inclination of about 2.4(H) to 1(V) which is slightly steeper than the design inclination of 2.5(H) to 1(V). The downstream slope is at an inclination of about 1.5(H) to 1(V), the angle of natural repose for the dumped cobber reject. The downsteam slope is thus much steeper than the design inclination of 2.5(H) to 1(V).

The vertical and horizontal alignment of the dam crest do not appear to be disturbed by deformation. No evidence of detrimental settlement, depressions, cracking or sinkhole development was found during the inspection. No animal burrows were found.

Clear water at a rate of about 1800 gal/min was discharging from the toe drain. Width of the discharge area was about 100 ft. Clear seepage of about 5 gal/min was also seen exiting from the toe near the right abutment. At both locations, no erosion was taking place.

There is no vegetation on the coarse material portions of dam. Some weeds were growing on the impervious blanket but these presented no hazard to the dam.

c. **Appurtenant structures.** There are no appurtenant structures at this dam.

d. **Reservoir area.** At the time of our inspection there was up to about 80 ft of fine tailings in the upstream portion of the reservoir (see Overview Photo, page iv). Elevation of the exposed tailings was about 870 to 880 ft (MSL). Elevation of the water surface on the upstream dam face was about 870 ft (MSL). Slopes surrounding the reservoir are relatively flat and showed no signs of instability at the time of the visual inspection.

e. **Downstream channel.** The channel downstream from the toe drain is in natural soil and is not lined. However, the cobber reject covers the stream bottom and a portion of the sides from the dam to its junction with Mary's Creek. The soil is moderately erodible but downward erosion is controlled by rock outcrops. The channel passes under a railroad bridge where floating debris could result in reduced flow capacity.

## 3.2 Evaluation

The downstream slope, which has assumed its natural angle of repose by end dumping from the dam crest, is very steep. Although no slides were observed, the slope surface is considered to be close to incipient failure. At its present inclination, the exposed portion of the upstream slope appears to be stable under the conditions observed during the inspection. No other signs of instability were noted.

The lack of a spillway and discharge through the embankment are discussed in Section 7.

# SECTION 4
# OPERATIONAL PROCEDURES

## 4.1 Procedures

The dam is still under construction. Procedures in effect have been described in Sections 1.2 and 3.1.

## 4.2 Maintenance of Dam

No maintenance of the dam in the usual sense is being performed as dam is still under construction. The dam width is being added to by addition of material to the downstream slope. The impermiable blanket is being raised on the upstream slope as the elevation of the fine tailings and reservoir level increases.

## 4.3 Maintenance of Operating Facilities

There are no operating facilities at this dam.

## 4.4 Description of Any Warning System in Effect

No warning system was found to be in effect at this project.

## 4.5 Evaluation

As the dam is still under construction, no operational or maintenance procedures are in effect. However, this is not considered a deficiency at this time but will need to be established upon completion of the dam.

The feasibility of a practical warning system should be evaluated to alert downstream residents should potentially hazardous conditions develop at the dam.

# SECTION 5
# HYDRAULIC/HYDROLOGIC

## 5.1 Evaluation of Features

a. Design data. No hydrologic or hydraulic information applicable to the present conditions was available for evaluation of the dam. Pertinent dimensions of the dam and reservoir were surveyed on 12 August 1980, measured during the field inspection or estimated from topographic mapping. The maps used in the analysis were the USGS Meramec State Park and Anthonies Mill 7.5-minute quadrangle maps.

b. Experience data. No recorded history of rainfall, runoff, discharge or pool stage data were available for this reservoir or watershed. According to Mr Emery, the dam has not been overtopped since the beginning of construction in 1961.

c. Visual observations. Conditions were noted which could lead to a reduced downstream channel capacity at a railroad bridge during a flood occurrence. Seepage of approximately 1800 gpm was observed at the toe drain during the visual inspection.

d. Overtopping potential. Hydrologic/hydraulic analyses indicate that the dam will not be overtopped by the 1 percent probability-of-occurrence (100 yr) event. These analyses also indicate that the dam in its present configuration will not be overtopped for a hydrologic event which produces the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

For the overtopping analysis, the seepage through the dam was not included in the evaluation. It is acknowledged that this assumption results in a conservative assessment of the overtopping potential. Since the assessment indicates a conservatively satisfactory condition, no further refinements of the analysis were deemed necessary.

The following data were computed for various flood events:

| Precipitation Event | Max. Reservoir WS Elevation ft | Max. Depth Over Dam ft | Maximum Outflow cfs | Duration of Overtopping hr |
|---|---|---|---|---|
| 50% PMF | 876.9 | 0 | 0 | 0 |
| 100% PMF | 882.3 | 0 | 0 | 0 |

The input data and output summaries for these analyses are included as Appendix B. Complete printouts for these analyses are on file.

The lack of a spillway in the present configuration of the dam and the controlled release of water through the pervious embankment materials are discussed in Section 7.

# SECTION 6
# STRUCTURAL STABILITY

## 6.1 Evaluation of Structural Stability

a. **Visual observations.** Results of the visual inspection of the dam are given in Section 3.1.b. There were no visual indications of structural instability of the dam. The vertical and horizontal alignment of the dam crest was not disturbed by deformation. There was no visual evidence of excessive settlement, depressions, sinkhole development, or cracking. Seepage from the toe drain was occurring in a manner consistent with the design intent; i.e. the quantity was not excessive, and the seepage water was not causing visible internal erosion of the dam or external erosion of the dam toe or downstream channel. There were only minimum indications of uncontrolled seepage occurring at one isolated point near the right abutment of the dam. The seepage at this point appeared to be through the dam and estimated to be about 5 gal/min; it was causing no visible erosion of the dam or downstream areas.

b. **Design and construction data.** Design data relating to the stability of the dam were available for review. In our review, it was found that the geotechnical properties of the embankment and foundation materials were not established by testing.

   Construction data were not available for review. The present configuration of the dam does not conform to the configurations analyzed in the design phase. Seepage and stability analyses for the as-built configuration of the dam were not available, which is considered a deficiency.

c. **Operating records.** No operating records were available.

d. **Post construction changes.** As the dam is still under construction, there are no post construction changes.

e. **Seismic stability.** The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analyses are available for review of the dam in its present configuration, the seismic stability cannot

be evaluated. However, as the embankment consists of loose coarse granular material and the downstream slope is near incipient failure, it is expected that substantial deformation of the embankment faces could occur in the event of a severe seismic event.

In consideration of the 38-ft elevation difference between the dam crest and water surface and the 110-ft wide crest, it is our preliminary opinion that for the present dam and storage configuration the likelihood of complete embankment failure due to a severe seismic event is remote.

# SECTION 7
# ASSESSMENT/REMEDIAL MEASURES

## 7.1 Dam Assessment

a. **Safety.** Based on the visual inspection and evaluation of the available data, Pea Ridge Mine Dam is judged to be in generally good condition in its present configuration. The dam is not yet completed.

There was no evidence of sinkhole development, cracking, depressions, detrimental settlement or slides. The downstream slope, however, is very steep and near the angle of repose for the cobber reject, and is considered to be in a state of incipient failure. In view of the 110-ft wide crest and elevation difference between the dam crest and present lake level, this is not considered to be a serious deficiency.

The dam at present does not have a spillway. For the PMF and other precipitation events, overtopping of the dam will not occur as there is sufficient storage volume in the reservoir. Therefore the lack of a spillway is not considered a deficiency for the present dam and storage configuration.

The functions of the dam are to impound water-borne fine tailings produced by the ore processing operations and to provide for the controlled release of water from the reservoir. To perform the latter function, the dam is being constructed without an impervious core. The function of the upstream clay blanket is to inhibit the migration of the fine tailings into the pervious cobber reject dam material. Water freely enters the upstream face above the clay blanket, seeps through the embankment, is collected in rock-filled trenches, and exits the dam through a toe drain. No piping or erosion was observed resulting from this practice; the discharge water was quite clear. No evidence of seepage on the downstream slope, other than at the toe, was noted. It appears that the seepage is not having a detrimental effect on the dam with the current elevation of the impounded lake.

Seepage and stability analyses for the dam, as constructed, are not available. This is a deficiency which should be rectified to meet the recommended guidelines.

b. **Adequacy of information.** The lack of stability and seepage analyses for the dam, as presently constructed as recommended in the guidelines, precludes an evaluation of the structural and seismic stability of the dam. This is considered a deficiency.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated as soon as practical.

d. **Necessity for Phase II.** In accordance with the Recommended Guidelines for Safety Inspections of Dams, the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed to complete the assessment of the dam are described in Section 7.2.b. It is our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

## 7.2 Remedial Measures

a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these options are:

1. Remove the dam, or breach it to prevent storage of water.

2. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.

3. Provide a highly reliable flood warning system (generally does not prevent damage but diminishes chances for loss of life).

b. **Remedial measures.** Based on our inspection of the Pea Ridge Mine Dam, it is recommended that the owner commission a review of the original design in order to re-evaluate, as a minimum, the following topics:

1. Determine the adequacy (or otherwise) of the existing configuration of the downstream slope, including the increased steepness of the downstream slope, but also the increased width of the crest.

2. Make a comparison of the anticipated vs observed seepage rates and draw appropriate conclusions.

3. Make stability analyses, including earthquake effects for the current and final construction phases.

4. Determine the need for and configuration of a spillway for the final phase of dam construction.

c. **O & M procedures.** Upon completion of the dam, a program of periodic inspections should be implemented. The inspections should report maintenance requirements. Records of the inspections and maintenance should be kept.

All remedial measurements should be performed under the guidance of an engineer experienced in the design and construction of dams.

## REFERENCES

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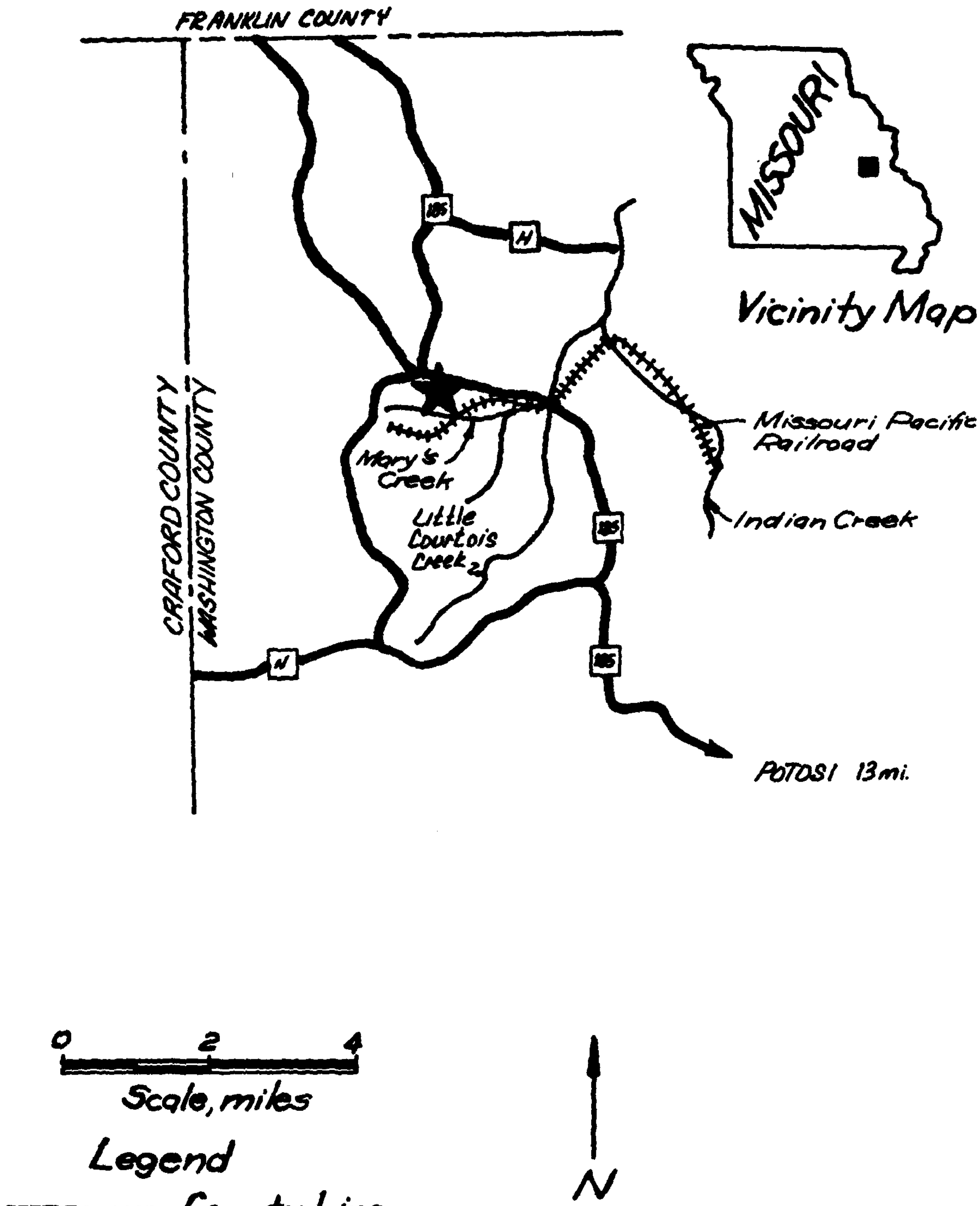
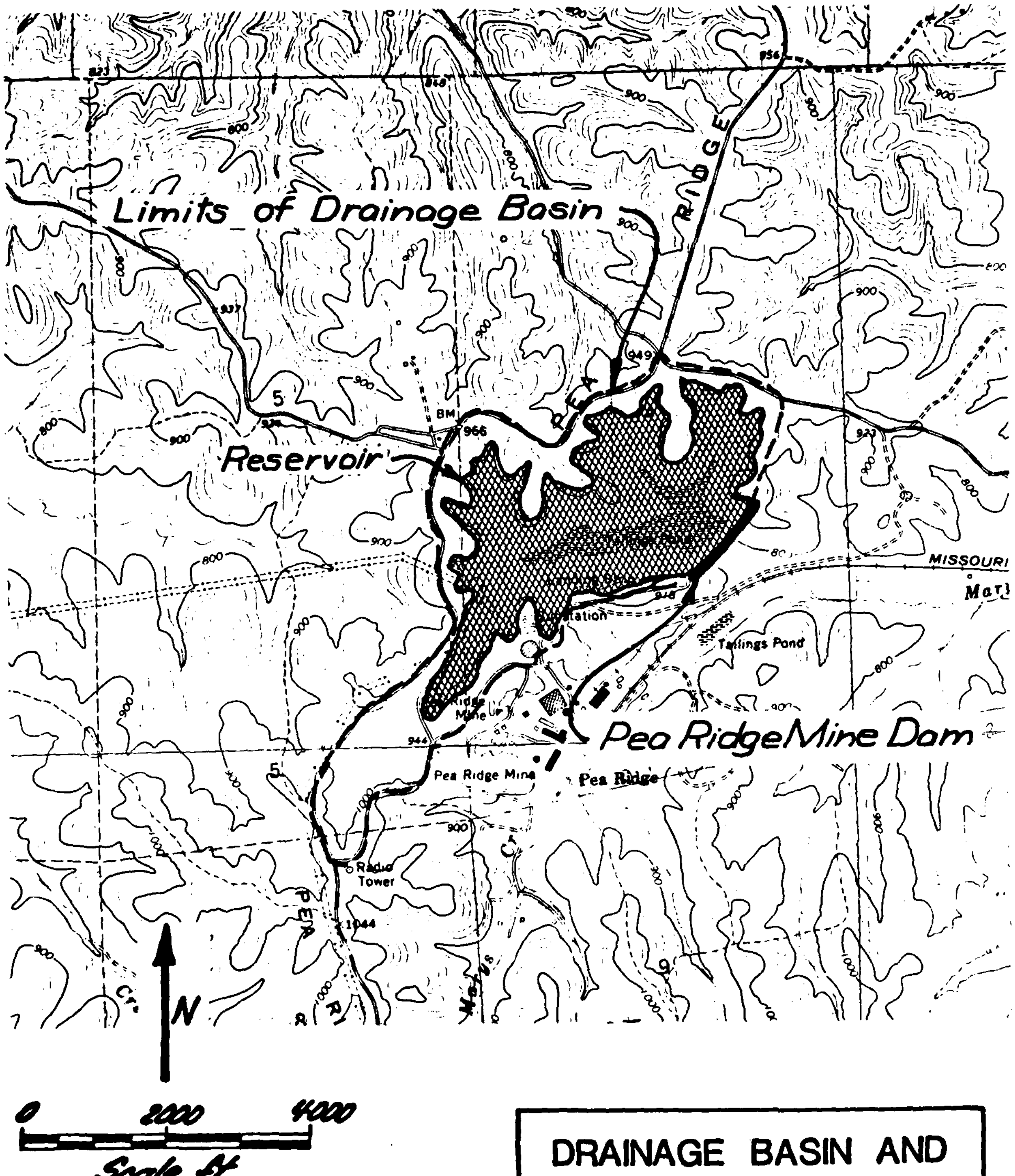
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.




Legend

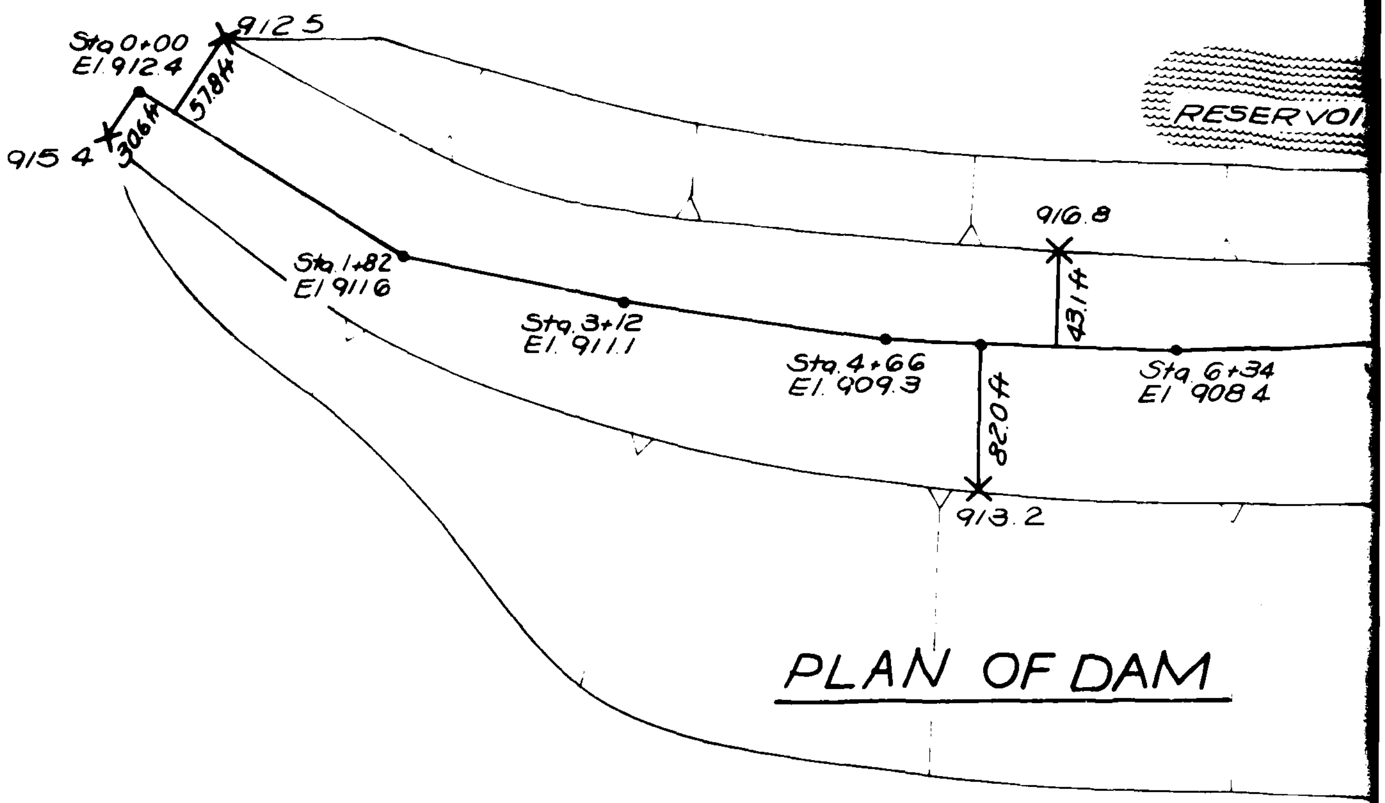
County Line
State highway and Route No.
River or Creek
City or Town
Project location

| SITE LOCATION MAP | |
|---|---|
| PEA RIDGE MINE DAM | |
| MO 30473 | Fig. 1 |

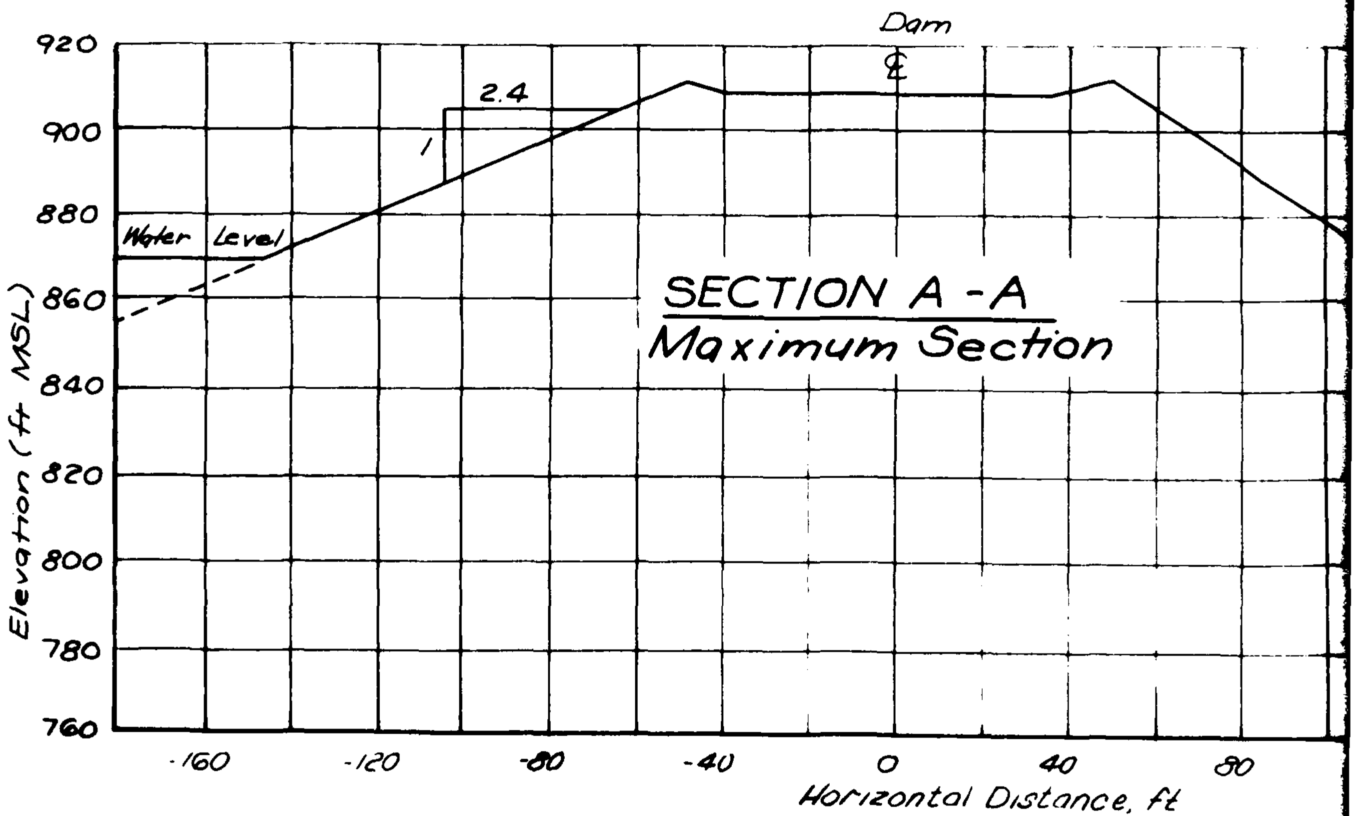



1. Topography obtained from USGS Meramec State Park and Anthonies Mill 7½ minute quadrangle maps.

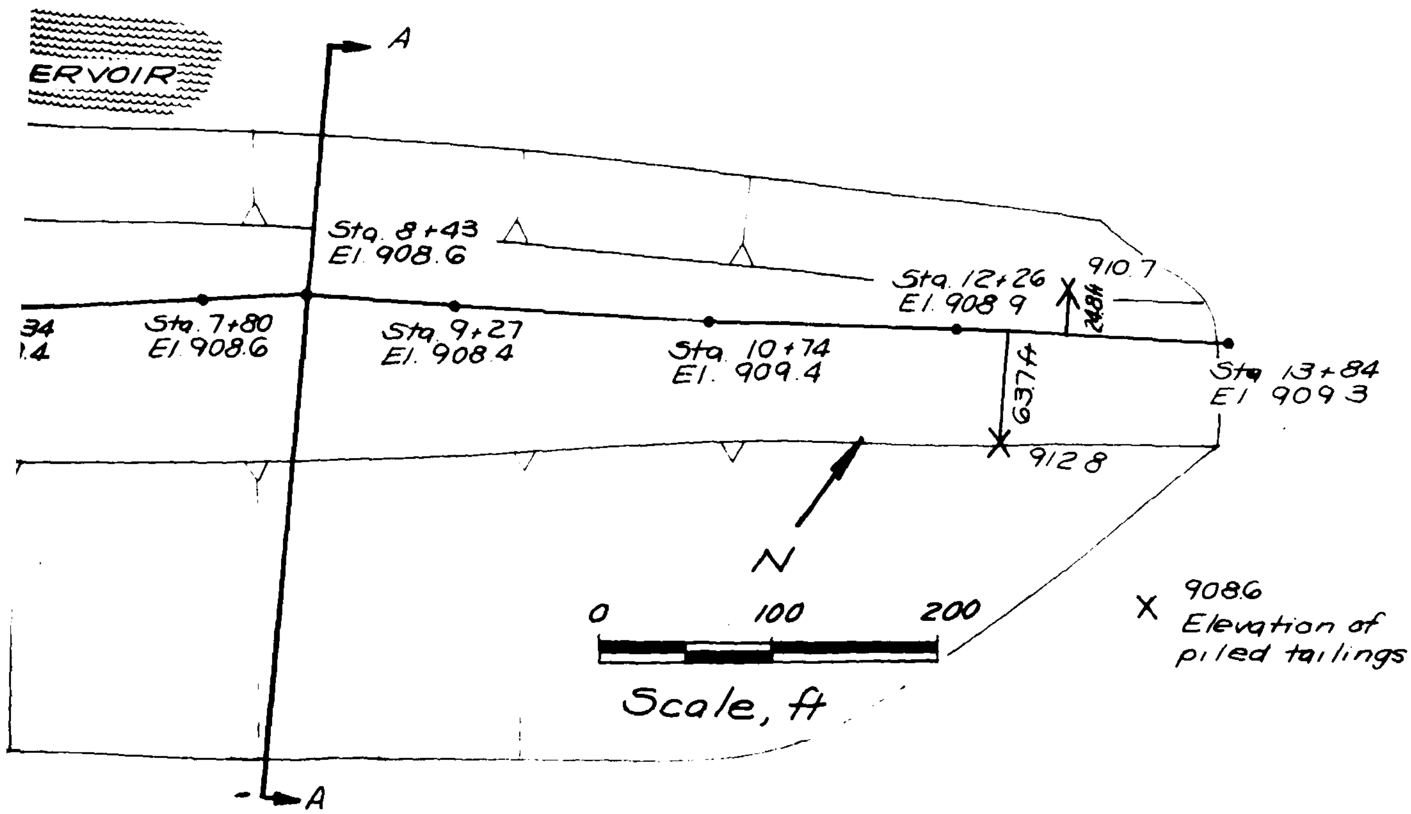
| DRAINAGE BASIN AND SITE TOPOGRAPHY | |
|---|---|
| PEA RIDGE MINE DAM | |
| MO 30473 | Fig. 2 |

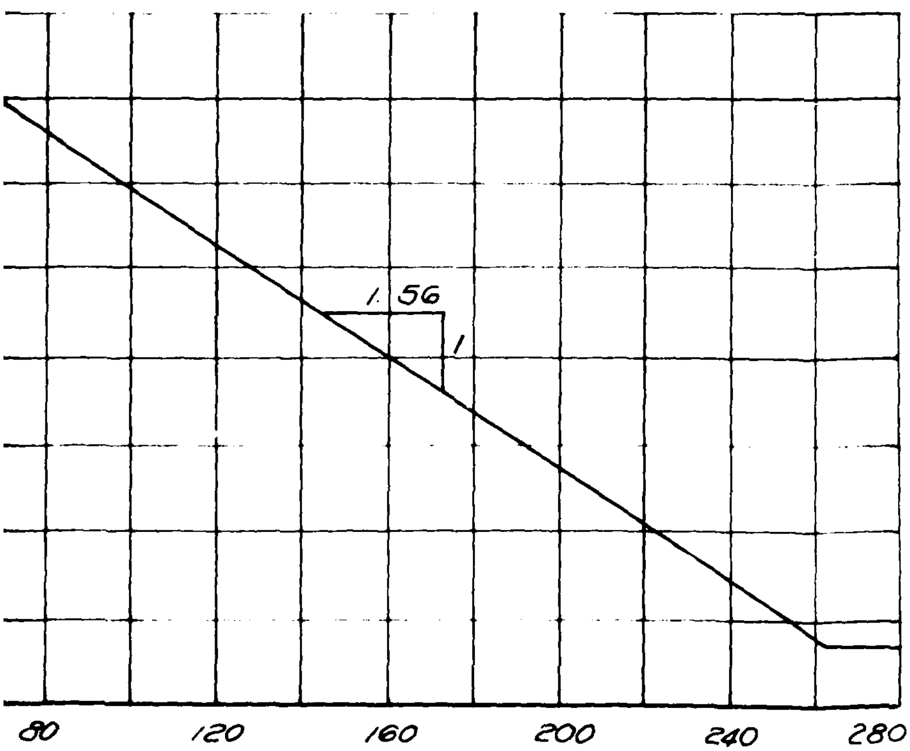



## PLAN OF DAM




## SECTION A - A
Maximum Section

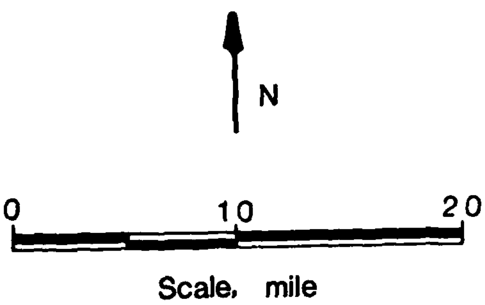



PLAN AND SECTION OF DAM

PEA RIDGE MINE DAM

| | |
|---|---|
| MO 30473 | Fig. 3 |

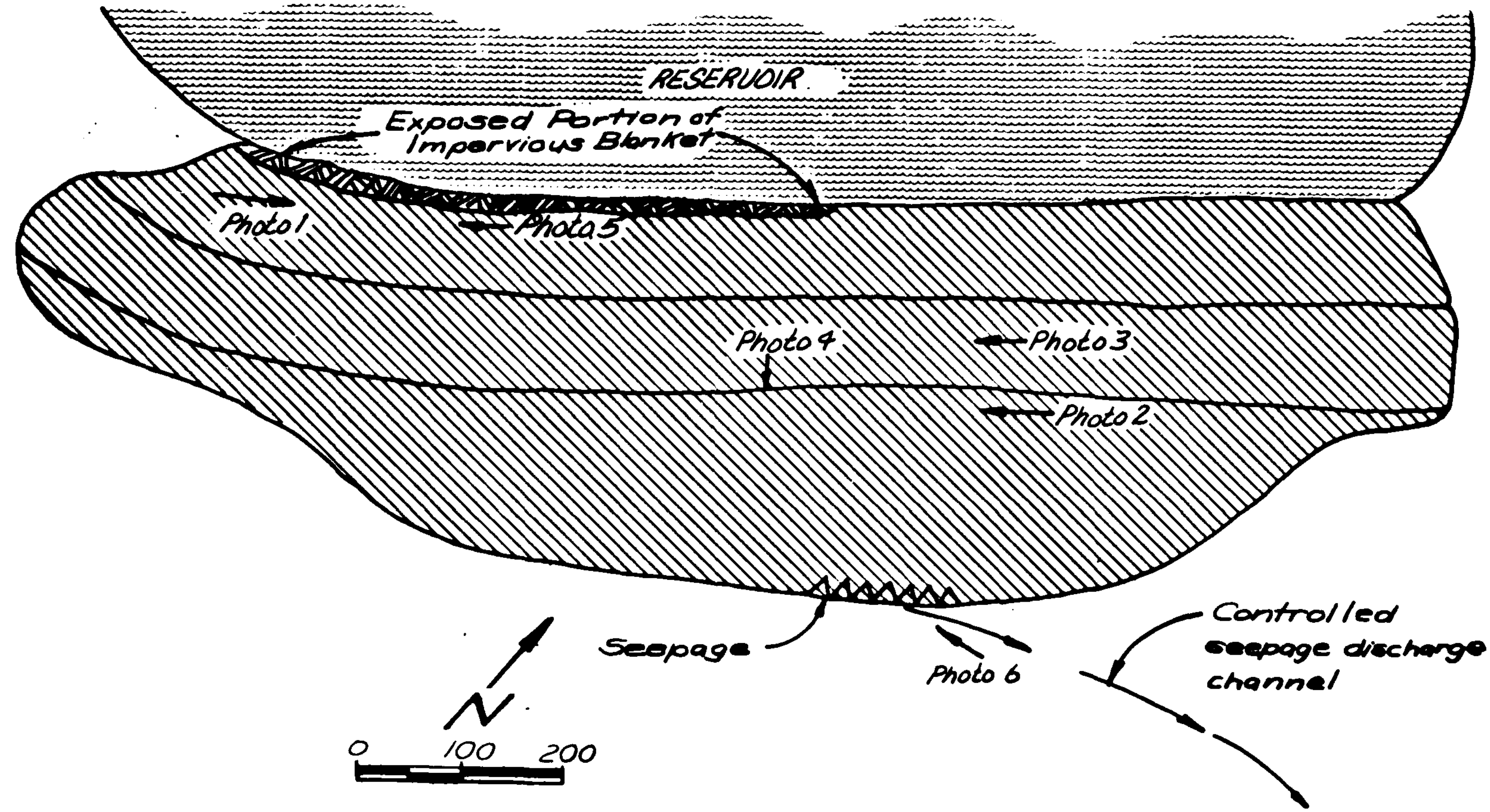

## Legend

- Or — Roubidoux Formation
- Gasconade Dolomite
  - Gunter Sandstone Member
- Cep — Eminence Dolomite
- Potosi Dolomite
- Ceb — Derby-Doerun Dolomite
- Davis Formation
- Bonneterre Formation
  - Whetstone Creek Member
  - Sullivan Siltstone Member
- *Reagan Sandstone* (subsurface, western Missouri)
- Lamotte Sandstone
- Diabase (dikes and sills)
- St. Francois Mountains Intrusive Suite
- St. Francois Mountains Volcanic Supergroup

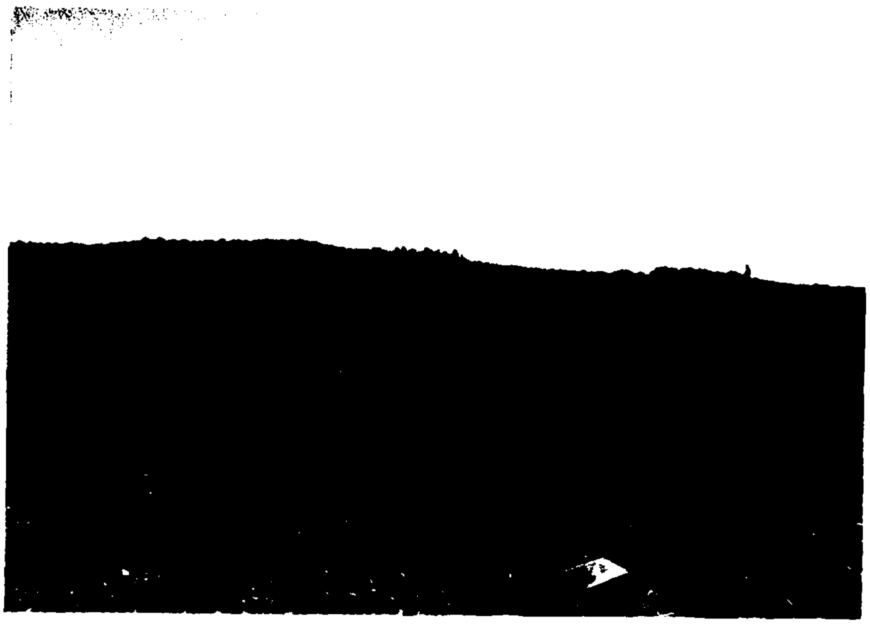
| REGIONAL GEOLOGIC MAP | |
|---|---|
| PEA RIDGE MINE DAM | |
| MO 30473 | Fig. 4 |

# APPENDIX A

Photographs

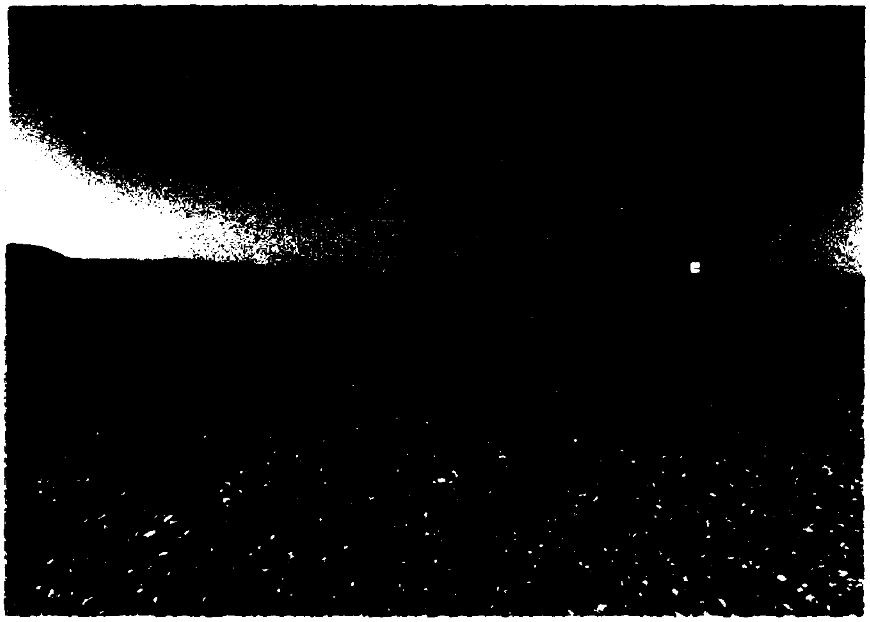



| PHOTO LOCATION SKETCH | |
|---|---|
| PEA RIDGE MINE DAM | |
| MO 30473 | Fig. A-1 |

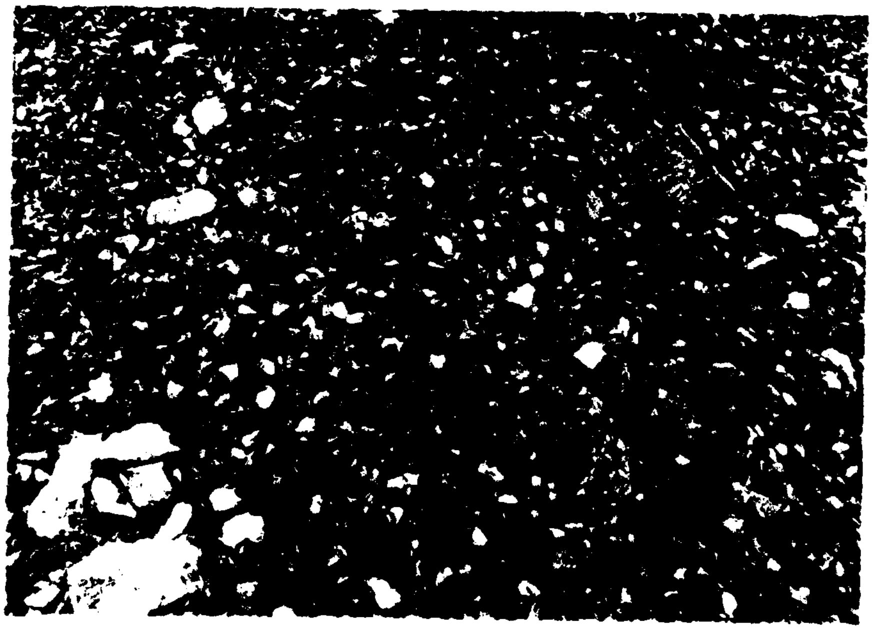


1. Upstream slope looking toward left abutment. Impervious blanket being placed at lower left.

2. Downstream slope from crest, looking toward right abutment.

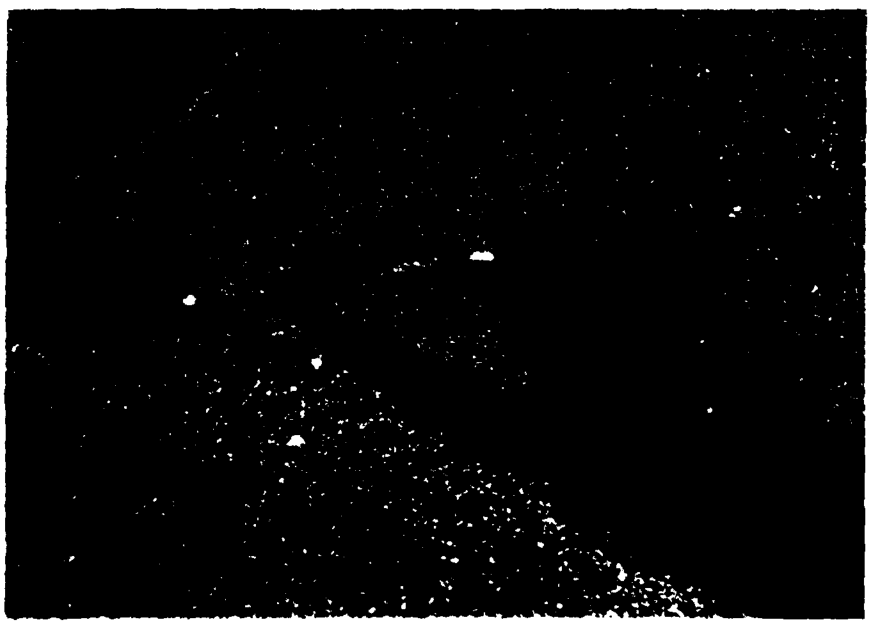


3. View along dam crest looking toward right abutment.



4 Close-up of coarse tailings used to construct dam.
Lens cap at center is 2.5 in. in diameter.

5. Impervious blanket material being placed on upstream slope.



6. Discharge from downstream toe of dam of about 1800 gal/min .

# APPENDIX B

*Hydraulic/Hydrologic Data and Analyses*

# APPENDIX B
## Hydraulic/Hydrologic Data and Analyses

B.1 Procedures

a. General. The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. Inflow hydrographs were developed and subsequently routed, by the modified Puls option, through the reservoir to determine if the events analysed would overtop the dam.

b. Precipitation events. The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St. Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956).

c. Unit hydrograph. The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (National Engineering Handbook, Section 4, Hydrology, 1971) was used in the analysis. This method was selected because of its simplicity, applicability to drainage areas less than 10 $mi^2$, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{\ell^{0.8}(s+1)^{0.7}}{1900\ Y^{0.5}} \qquad \text{(Equation 15-4)}$$

where: $L$ = lag in hours
$\ell$ = hydraulic length of the watershed in feet
$s = \frac{1000}{CN} - 10$ where CN = hydrologic soil curve number
$Y$ = average watershed land slope in percent

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \qquad \text{(Equation 15-3)}$$

where: $T_c$ = time of concentration in hours

$L$ = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133T_c \qquad \text{(Equation 16-12)}$$

where: $\Delta D$ = duration of unit excess rainfall
$T_c$ = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 5 minutes was used.

d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover, and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF events and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

e. Starting elevations. The starting water elevation for the various PMF events was established based on an antecedent storm equal to half of the subject storm, i.e., 25% PMF for the 50% storm and 50% for 100% of the PMF. Starting elevation for the 50% PMF analysis was 873.0 ft. Starting elevation for 100% PMF was 875.0 ft.

f. Spillway rating curve. Not applicable.

B.2 Pertinent Data

a. Drainage area. 0.57 mi$^2$.

b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 24 hours duration was divided into 5 minute intervals in order to develop the inflow hydrograph.

c. Lag time. 0.4 hrs.

d. Hydrologic soil group. C

e. SCS curve numbers.

1. For PMF- AMC III - Curve Number 92
2. For 1 and 10 percent probability-of-occurrence events AMC II - Curve Number 81

f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Meramec State Park and Anthonies Mill 7.5 minute quadrangle maps. The data were entered on the $A and $E cards so that the HEC-1 program could compute storage volumes.

g. Outflow over dam crest. Sufficient storage is available to preclude overflow over the dam crest.

h. Outflow capacity. No spillway has been constructed for this dam. The seepage through the dam was neglected for the overtopping analysis. This results in a conservative analysis.

B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.

```
***********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
***********************************
A1       PEA RIDGE MINE DAM NO. 30473
A2       WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB NO. 79CH009
A3       PROBABLE MAXIMUM FLOW (PMF) ANALYSIS
B     288      0       5      -0      -0      -0      -0      -0      -0      -0
B1      5
J       1      1       1
J1     .5
K       0   LAKE                                       1
K1       INFLOW HYDROGRAPH COMPUTATIONS
M       1      2     .57                      1.0
P       0     26     102     120     130
T                                              -1     -92             .33
W2            .4
X      -1   -.05       5
K       1    DAM
K1       FLOOD ROUTING AND OVERTOPPING ANALYSIS
Y                              1       1
Y1      1                                  -873.0
$A     0.   33.7    61.0   100.0   140.0   185.0   240.0
$E  800.0  820.0   840.0   860.0   880.0   900.0   920.0
$$912.00     0.     3.0     1.5
$D  908.4    2.6     1.5
$L     0.  370.0   610.0   950.0  1000.0  1060.0  1360.0  1384.0
$V  908.4  908.6   909.0   909.4   910.0   911.0   912.0   912.4
K      99
```

Input Data
50% PMF Event
Pea Ridge Mine Dam
MO  30473

B4

Output Summary
50% PMF Event
Pea Ridge Mine Dam
MO 30473

B5

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE: 20 AUG 80
     TIME: 13.08.41

                         PEA RIDGE MINE DAM NO. 30473
                         WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB NO. 79CH009
                         PROBABLE MAXIMUM FLOW (PMF) ANALYSIS

                                    JOB SPECIFICATION
          NQ      NHR     NMIN     IDAY      IHR     IMIN    METRC     IPLT     IPRT    NSTAN
         200        0        5       -0       -0       -0       -0       -0       -0       -0
                                  JOPER      NWT    LROPT    TRACE
                                      5       -0       -0       -0

                         MULTI-PLAN ANALYSES TO BE PERFORMED
                               NPLAN= 1 NRTIO= 1 LRTIO= 1
     RTIOS=     .50

**********          **********          **********          **********          **********

                              SUB-AREA RUNOFF COMPUTATION

     INFLOW HYDROGRAPH COMPUTATIONS

              ISTAQ    ICOMP    IECON    ITAPE     JPLT     JPRT    INAME   ISTAGE    IAUTO
               LAKE        0       -0       -0       -0       -0        1       -0       -0

                                    HYDROGRAPH DATA
      IHYDG    IUHG    TAREA     SNAP    TRSDA    TRSPC    RATIO    ISNOW    ISAME    LOCAL
          1       2      .57      -0.      .57     1.00      -0.       -0       -0       -0

                                      PRECIP DATA
               SPFE      PMS       R6      R12      R24      R48      R72      R96
                 0.    26.00   102.00   120.00   130.00      -0.      -0.      -0.

                                       LOSS DATA
     LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
        0      0.      0.    1.00      0.      0.    1.00   -1.00  -92.00     -0.     .33

          CURVE NO =  -92.00  WETNESS =    -1.00  EFFECT CN =    92.00

                                 UNIT HYDROGRAPH DATA
                              TC= -0.       LAG=    .40

                                    RECESSION DATA
                        STRTQ=    -1.00     QRCSN=    -.05     RTIOR= 5.00

     UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC=    -0.    HOURS, LAG=    .40   VOL= 1.00
       57.      176.      371.      549.      620.      605.      526.      417.      288.      211.
      157.      117.       89.       65.       48.       35.       25.       18.       13.       10.
        7.        6.        4.        3.        2.        1.
```

UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .40 VOL= 1.00

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 57. | 176. | 371. | 549. | 620. | 605. | 526. | 417. | 288. | 211. |
| 157. | 117. | 85. | 63. | 46. | 33. | 25. | 18. | 13. | 10. |
| 7. | 6. | 4. | 3. | 2. | 1. | | | | |

0

END-OF-PERIOD FLOW

| MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q | MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | .05 | 1 | .01 | .00 | .01 | 1. | 1.01 | 12.05 | 145 | .22 | .22 | .00 | 252. |
| 1.01 | .10 | 2 | .01 | .00 | .01 | 2. | 1.01 | 12.10 | 146 | .22 | .22 | .00 | 315. |
| 1.01 | .15 | 3 | .01 | .00 | .01 | 3. | 1.01 | 12.15 | 147 | .22 | .22 | .00 | 376. |
| 1.01 | .20 | 4 | .01 | .00 | .01 | 6. | 1.01 | 12.20 | 148 | .22 | .22 | .00 | 461. |
| 1.01 | .25 | 5 | .01 | .00 | .01 | 9. | 1.01 | 12.25 | 149 | .22 | .22 | .00 | 557. |
| 1.01 | .30 | 6 | .01 | .00 | .01 | 12. | 1.01 | 12.30 | 150 | .22 | .22 | .00 | 651. |
| 1.01 | .35 | 7 | .01 | .00 | .01 | 14. | 1.01 | 12.35 | 151 | .22 | .22 | .00 | 732. |
| 1.01 | .40 | 8 | .01 | .00 | .01 | 16. | 1.01 | 12.40 | 152 | .22 | .22 | .00 | 797. |
| 1.01 | .45 | 9 | .01 | .00 | .01 | 17. | 1.01 | 12.45 | 153 | .22 | .22 | .00 | 842. |
| 1.01 | .50 | 10 | .01 | .00 | .01 | 18. | 1.01 | 12.50 | 154 | .22 | .22 | .00 | 879. |
| 1.01 | .55 | 11 | .01 | .00 | .01 | 19. | 1.01 | 12.55 | 155 | .22 | .22 | .00 | 859. |
| 1.01 | 1.00 | 12 | .01 | .00 | .01 | 20. | 1.01 | 13.00 | 156 | .22 | .22 | .00 | 918. |
| 1.01 | 1.05 | 13 | .01 | .00 | .01 | 20. | 1.01 | 13.05 | 157 | .27 | .26 | .00 | 934. |
| 1.01 | 1.10 | 14 | .01 | .01 | .01 | 20. | 1.01 | 13.10 | 158 | .27 | .26 | .00 | 952. |
| 1.01 | 1.15 | 15 | .01 | .01 | .01 | 21. | 1.01 | 13.15 | 159 | .27 | .26 | .00 | 975. |
| 1.01 | 1.20 | 16 | .01 | .01 | .01 | 21. | 1.01 | 13.20 | 160 | .27 | .26 | .00 | 1009. |
| 1.01 | 1.25 | 17 | .01 | .01 | .01 | 22. | 1.01 | 13.25 | 161 | .27 | .26 | .00 | 1037. |
| 1.01 | 1.30 | 18 | .01 | .01 | .01 | 22. | 1.01 | 13.30 | 162 | .27 | .26 | .00 | 1066. |
| 1.01 | 1.35 | 19 | .01 | .01 | .01 | 23. | 1.01 | 13.35 | 163 | .27 | .26 | .00 | 1092. |
| 1.01 | 1.40 | 20 | .01 | .01 | .01 | 24. | 1.01 | 13.40 | 164 | .27 | .26 | .00 | 1112. |
| 1.01 | 1.45 | 21 | .01 | .01 | .01 | 25. | 1.01 | 13.45 | 165 | .27 | .26 | .00 | 1126. |
| 1.01 | 1.50 | 22 | .01 | .01 | .01 | 26. | 1.01 | 13.50 | 166 | .27 | .26 | .00 | 1137. |
| 1.01 | 1.55 | 23 | .01 | .01 | .01 | 27. | 1.01 | 13.55 | 167 | .27 | .26 | .00 | 1144. |
| 1.01 | 2.00 | 24 | .01 | .01 | .01 | 28. | 1.01 | 14.00 | 168 | .27 | .26 | .00 | 1150. |
| 1.01 | 2.05 | 25 | .01 | .01 | .01 | 29. | 1.01 | 14.05 | 169 | .33 | .33 | .00 | 1158. |
| 1.01 | 2.10 | 26 | .01 | .01 | .01 | 30. | 1.01 | 14.10 | 170 | .33 | .33 | .00 | 1173. |
| 1.01 | 2.15 | 27 | .01 | .01 | .01 | 31. | 1.01 | 14.15 | 171 | .33 | .33 | .00 | 1200. |
| 1.01 | 2.20 | 28 | .01 | .01 | .01 | 32. | 1.01 | 14.20 | 172 | .33 | .33 | .00 | 1238. |
| 1.01 | 2.25 | 29 | .01 | .01 | .01 | 33. | 1.01 | 14.25 | 173 | .33 | .33 | .00 | 1280. |
| 1.01 | 2.30 | 30 | .01 | .01 | .01 | 34. | 1.01 | 14.30 | 174 | .33 | .33 | .00 | 1321. |
| 1.01 | 2.35 | 31 | .01 | .01 | .01 | 34. | 1.01 | 14.35 | 175 | .33 | .33 | .00 | 1357. |
| 1.01 | 2.40 | 32 | .01 | .01 | .01 | 35. | 1.01 | 14.40 | 176 | .33 | .33 | .00 | 1385. |
| 1.01 | 2.45 | 33 | .01 | .01 | .01 | 36. | 1.01 | 14.45 | 177 | .33 | .33 | .00 | 1405. |
| 1.01 | 2.50 | 34 | .01 | .01 | .01 | 37. | 1.01 | 14.50 | 178 | .33 | .33 | .00 | 1419. |
| 1.01 | 2.55 | 35 | .01 | .01 | .01 | 37. | 1.01 | 14.55 | 179 | .33 | .33 | .00 | 1430. |
| 1.01 | 3.00 | 36 | .01 | .01 | .01 | 38. | 1.01 | 15.00 | 180 | .33 | .33 | .00 | 1438. |
| 1.01 | 3.05 | 37 | .01 | .01 | .00 | 39. | 1.01 | 15.05 | 181 | .20 | .20 | .00 | 1436. |
| 1.01 | 3.10 | 38 | .01 | .01 | .00 | 39. | 1.01 | 15.10 | 182 | .40 | .40 | .00 | 1429. |
| 1.01 | 3.15 | 39 | .01 | .01 | .00 | 40. | 1.01 | 15.15 | 183 | .40 | .40 | .00 | 1420. |
| 1.01 | 3.20 | 40 | .01 | .01 | .00 | 40. | 1.01 | 15.20 | 184 | .60 | .60 | .00 | 1437. |
| 1.01 | 3.25 | 41 | .01 | .01 | .00 | 41. | 1.01 | 15.25 | 185 | .71 | .70 | .00 | 1510. |
| 1.01 | 3.30 | 42 | .01 | .01 | .00 | 42. | 1.01 | 15.30 | 186 | 1.71 | 1.71 | .00 | 1708. |
| 1.01 | 3.35 | 43 | .01 | .01 | .00 | 42. | 1.01 | 15.35 | 187 | 2.82 | 2.82 | .00 | 2151. |
| 1.01 | 3.40 | 44 | .01 | .01 | .00 | 43. | 1.01 | 15.40 | 188 | 1.11 | 1.11 | .00 | 2855. |
| 1.01 | 3.45 | 45 | .01 | .01 | .00 | 43. | 1.01 | 15.45 | 189 | .71 | .70 | .00 | 3725. |
| 1.01 | 3.50 | 46 | .01 | .01 | .00 | 44. | 1.01 | 15.50 | 190 | .60 | .60 | .00 | 4443. |
| 1.01 | 3.55 | 47 | .01 | .01 | .00 | 44. | 1.01 | 15.55 | 191 | .40 | .40 | .00 | 4780. |
| 1.01 | 4.00 | 48 | .01 | .01 | .00 | 44. | 1.01 | 16.00 | 192 | .40 | .40 | .00 | 4742. |
| 1.01 | 4.05 | 49 | .01 | .01 | .00 | 45. | 1.01 | 16.05 | 193 | .31 | .31 | .00 | 4407. |
| 1.01 | 4.10 | 50 | .01 | .01 | .00 | 45. | 1.01 | 16.10 | 194 | .31 | .31 | .00 | 3888. |
| 1.01 | 4.15 | 51 | .01 | .01 | .00 | 46. | 1.01 | 16.15 | 195 | .31 | .31 | .00 | 3319. |
| 1.01 | 4.20 | 52 | .01 | .01 | .00 | 46. | 1.01 | 16.20 | 196 | .31 | .31 | .00 | 2858. |
| 1.01 | 4.25 | 53 | .01 | .01 | .00 | 46. | 1.01 | 16.25 | 197 | .31 | .31 | .00 | 2453. |
| 1.01 | 4.30 | 54 | .01 | .01 | .00 | 47. | 1.01 | 16.30 | 198 | .31 | .31 | .00 | 2202. |
| 1.01 | 4.35 | 55 | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | |

Output Summary
50% PMF Event
Pea Ridge Mine Dam
MO 30473

B6

Output Summary
50% PMF Event
Pea Ridge Mine Dam
MO 30473

B7

| | | | | | | |
|---|---|---|---|---|---|---|
| 1.01 | 4.25 | 53 | .01 | .01 | .00 | 46. |
| 1.01 | 4.30 | 54 | .01 | .01 | .00 | 47. |
| 1.01 | 4.35 | 55 | .01 | .01 | .00 | 47. |
| 1.01 | 4.40 | 56 | .01 | .01 | .00 | 47. |
| 1.01 | 4.45 | 57 | .01 | .01 | .00 | 48. |
| 1.01 | 4.50 | 58 | .01 | .01 | .00 | 48. |
| 1.01 | 4.55 | 59 | .01 | .01 | .00 | 48. |
| 1.01 | 5.00 | 60 | .01 | .01 | .00 | 49. |
| 1.01 | 5.05 | 61 | .01 | .01 | .00 | 49. |
| 1.01 | 5.10 | 62 | .01 | .01 | .00 | 49. |
| 1.01 | 5.15 | 63 | .01 | .01 | .00 | 50. |
| 1.01 | 5.20 | 64 | .01 | .01 | .00 | 50. |
| 1.01 | 5.25 | 65 | .01 | .01 | .00 | 50. |
| 1.01 | 5.30 | 66 | .01 | .01 | .00 | 50. |
| 1.01 | 5.35 | 67 | .01 | .01 | .00 | 51. |
| 1.01 | 5.40 | 68 | .01 | .01 | .00 | 51. |
| 1.01 | 5.45 | 69 | .01 | .01 | .00 | 51. |
| 1.01 | 5.50 | 70 | .01 | .01 | .00 | 51. |
| 1.01 | 5.55 | 71 | .01 | .01 | .00 | 52. |
| 1.01 | 6.00 | 72 | .01 | .01 | .00 | 52. |
| 1.01 | 6.05 | 73 | .07 | .05 | .01 | 54. |
| 1.01 | 6.10 | 74 | .07 | .06 | .01 | 62. |
| 1.01 | 6.15 | 75 | .07 | .06 | .01 | 78. |
| 1.01 | 6.20 | 76 | .07 | .06 | .01 | 102. |
| 1.01 | 6.25 | 77 | .07 | .06 | .01 | 129. |
| 1.01 | 6.30 | 78 | .07 | .06 | .01 | 156. |
| 1.01 | 6.35 | 79 | .07 | .06 | .01 | 180. |
| 1.01 | 6.40 | 80 | .07 | .05 | .01 | 200. |
| 1.01 | 6.45 | 81 | .07 | .06 | .01 | 214. |
| 1.01 | 6.50 | 82 | .07 | .06 | .01 | 225. |
| 1.01 | 6.55 | 83 | .07 | .06 | .01 | 233. |
| 1.01 | 7.00 | 84 | .07 | .06 | .01 | 240. |
| 1.01 | 7.05 | 85 | .07 | .06 | .01 | 246. |
| 1.01 | 7.10 | 86 | .07 | .06 | .00 | 250. |
| 1.01 | 7.15 | 87 | .07 | .06 | .00 | 253. |
| 1.01 | 7.20 | 88 | .07 | .06 | .00 | 256. |
| 1.01 | 7.25 | 89 | .07 | .06 | .00 | 259. |
| 1.01 | 7.30 | 90 | .07 | .06 | .00 | 261. |
| 1.01 | 7.35 | 91 | .07 | .06 | .00 | 263. |
| 1.01 | 7.40 | 92 | .07 | .06 | .00 | 264. |
| 1.01 | 7.45 | 93 | .07 | .06 | .00 | 265. |
| 1.01 | 7.50 | 94 | .07 | .06 | .00 | 267. |
| 1.01 | 7.55 | 95 | .07 | .06 | .00 | 268. |
| 1.01 | 8.00 | 96 | .07 | .06 | .00 | 269. |
| 1.01 | 8.05 | 97 | .07 | .06 | .00 | 270. |
| 1.01 | 8.10 | 98 | .07 | .05 | .00 | 270. |
| 1.01 | 8.15 | 99 | .07 | .06 | .00 | 271. |
| 1.01 | 8.20 | 100 | .07 | .05 | .00 | 272. |
| 1.01 | 8.25 | 101 | .07 | .06 | .00 | 272. |
| 1.01 | 8.30 | 102 | .07 | .06 | .00 | 273. |
| 1.01 | 8.35 | 103 | .07 | .06 | .00 | 274. |
| 1.01 | 8.40 | 104 | .07 | .06 | .00 | 274. |
| 1.01 | 8.45 | 105 | .07 | .06 | .00 | 275. |
| 1.01 | 8.50 | 106 | .07 | .06 | .00 | 275. |
| 1.01 | 8.55 | 107 | .07 | .06 | .00 | 275. |
| 1.01 | 9.00 | 108 | .07 | .06 | .00 | 276. |
| 1.01 | 9.05 | 109 | .07 | .06 | .00 | 276. |
| 1.01 | 9.10 | 110 | .07 | .06 | .00 | 277. |
| 1.01 | 9.15 | 111 | .07 | .06 | .00 | 277. |
| 1.01 | 9.20 | 112 | .07 | .05 | .00 | 277. |
| 1.01 | 9.25 | 113 | .07 | .06 | .00 | 278. |
| 1.01 | 9.30 | 114 | .07 | .05 | .00 | 278. |
| 1.01 | 9.35 | 115 | .07 | .06 | .00 | 278. |
| 1.01 | 9.40 | 116 | [illegible] | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1.01 | 16.20 | 196 | .31 | .31 | .00 | [illegible] |
| 1.01 | 16.25 | 197 | .31 | .31 | .00 | 2453. |
| 1.01 | 16.30 | 198 | .31 | .31 | .00 | 2202. |
| 1.01 | 16.35 | 199 | .31 | .31 | .00 | 1981. |
| 1.01 | 16.40 | 200 | .31 | .31 | .00 | 1818. |
| 1.01 | 16.45 | 201 | .31 | .31 | .00 | 1656. |
| 1.01 | 16.50 | 202 | .31 | .31 | .00 | 1607. |
| 1.01 | 16.55 | 203 | .31 | .31 | .00 | 1543. |
| 1.01 | 17.00 | 204 | .31 | .31 | .00 | 1496. |
| 1.01 | 17.05 | 205 | .24 | .24 | .00 | 1457. |
| 1.01 | 17.10 | 206 | .24 | .24 | .00 | 1420. |
| 1.01 | 17.15 | 207 | .24 | .24 | .00 | 1377. |
| 1.01 | 17.20 | 208 | .24 | .24 | .00 | 1328. |
| 1.01 | 17.25 | 209 | .24 | .24 | .00 | 1276. |
| 1.01 | 17.30 | 210 | .24 | .24 | .00 | 1227. |
| 1.01 | 17.35 | 211 | .24 | .24 | .00 | 1184. |
| 1.01 | 17.40 | 212 | .24 | .24 | .00 | 1151. |
| 1.01 | 17.45 | 213 | .24 | .24 | .00 | 1128. |
| 1.01 | 17.50 | 214 | .24 | .24 | .00 | 1113. |
| 1.01 | 17.55 | 215 | .24 | .24 | .00 | 1101. |
| 1.01 | 18.00 | 216 | .24 | .24 | .00 | 1093. |
| 1.01 | 18.05 | 217 | .02 | .02 | .00 | 1079. |
| 1.01 | 18.10 | 218 | .02 | .02 | .00 | 1031. |
| 1.01 | 18.15 | 219 | .02 | .02 | .00 | 946. |
| 1.01 | 18.20 | 220 | .02 | .02 | .00 | 822. |
| 1.01 | 18.25 | 221 | .02 | .02 | .00 | 684. |
| 1.01 | 18.30 | 222 | .02 | .02 | .00 | 548. |
| 1.01 | 18.35 | 223 | .02 | .02 | .00 | 421. |
| 1.01 | 18.40 | 224 | .02 | .02 | .00 | 338. |
| 1.01 | 18.45 | 225 | .02 | .02 | .00 | 274. |
| 1.01 | 18.50 | 226 | .02 | .02 | .00 | 230. |
| 1.01 | 18.55 | 227 | .02 | .02 | .00 | 196. |
| 1.01 | 19.00 | 228 | .02 | .02 | .00 | 167. |
| 1.01 | 19.05 | 229 | .02 | .02 | .00 | 147. |
| 1.01 | 19.10 | 230 | .02 | .02 | .00 | 133. |
| 1.01 | 19.15 | 231 | .02 | .02 | .00 | 123. |
| 1.01 | 19.20 | 232 | .02 | .02 | .00 | 118. |
| 1.01 | 19.25 | 233 | .02 | .02 | .00 | 110. |
| 1.01 | 19.30 | 234 | .02 | .02 | .00 | 106. |
| 1.01 | 19.35 | 235 | .02 | .02 | .00 | 103. |
| 1.01 | 19.40 | 236 | .02 | .02 | .00 | 101. |
| 1.01 | 19.45 | 237 | .02 | .02 | .00 | 99. |
| 1.01 | 19.50 | 238 | .02 | .02 | .00 | 98. |
| 1.01 | 19.55 | 239 | .02 | .02 | .00 | 97. |
| 1.01 | 20.00 | 240 | .02 | .02 | .00 | 96. |
| 1.01 | 20.05 | 241 | .02 | .02 | .00 | 96. |
| 1.01 | 20.10 | 242 | .02 | .02 | .00 | 96. |
| 1.01 | 20.15 | 243 | .02 | .02 | .00 | 96. |
| 1.01 | 20.20 | 244 | .02 | .02 | .00 | 96. |
| 1.01 | 20.25 | 245 | .02 | .02 | .00 | 96. |
| 1.01 | 20.30 | 246 | .02 | .02 | .00 | 96. |
| 1.01 | 20.35 | 247 | .02 | .02 | .00 | 96. |
| 1.01 | 20.40 | 248 | .02 | .02 | .00 | 96. |
| 1.01 | 20.45 | 249 | .02 | .02 | .00 | 96. |
| 1.01 | 20.50 | 250 | .02 | .02 | .00 | 96. |
| 1.01 | 20.55 | 251 | .02 | .02 | .00 | 96. |
| 1.01 | 21.00 | 252 | .02 | .02 | .00 | 96. |
| 1.01 | 21.05 | 253 | .02 | .02 | .00 | 96. |
| 1.01 | 21.10 | 254 | .02 | .02 | .00 | 96. |
| 1.01 | 21.15 | 255 | .02 | .02 | .00 | 96. |
| 1.01 | 21.20 | 256 | .02 | .02 | .00 | 96. |
| 1.01 | 21.25 | 257 | .02 | .02 | .00 | 96. |
| 1.01 | 21.30 | 258 | .02 | .02 | .00 | 96. |
| 1.01 | 21.35 | 259 | .02 | .02 | .00 | [illegible] |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | 9.30 | 114 | .07 | .06 | .00 | 278. | | 1.01 | 21.30 | 258 | .02 | .02 | .00 | 56. |
| 1.01 | 9.35 | 115 | .07 | .06 | .00 | 278. | | 1.01 | 21.35 | 259 | .02 | .02 | .00 | 56. |
| 1.01 | 9.40 | 116 | .07 | .06 | .00 | 278. | | 1.01 | 21.40 | 260 | .02 | .02 | .00 | 56. |
| 1.01 | 9.45 | 117 | .07 | .06 | .00 | 279. | | 1.01 | 21.45 | 261 | .02 | .02 | .00 | 56. |
| 1.01 | 9.50 | 118 | .07 | .06 | .00 | 279. | | 1.01 | 21.50 | 262 | .02 | .02 | .00 | 56. |
| 1.01 | 9.55 | 119 | .07 | .06 | .00 | 279. | | 1.01 | 21.55 | 263 | .02 | .02 | .00 | 56. |
| 1.01 | 10.00 | 120 | .07 | .06 | .00 | 279. | | 1.01 | 22.00 | 264 | .02 | .02 | .00 | 56. |
| 1.01 | 10.05 | 121 | .07 | .06 | .00 | 280. | | 1.01 | 22.05 | 265 | .02 | .02 | .00 | 56. |
| 1.01 | 10.10 | 122 | .07 | .06 | .00 | 280. | | 1.01 | 22.10 | 266 | .02 | .02 | .00 | 56. |
| 1.01 | 10.15 | 123 | .07 | .06 | .00 | 280. | | 1.01 | 22.15 | 267 | .02 | .02 | .00 | 56. |
| 1.01 | 10.20 | 124 | .07 | .06 | .00 | 280. | | 1.01 | 22.20 | 268 | .02 | .02 | .00 | 56. |
| 1.01 | 10.25 | 125 | .07 | .06 | .00 | 280. | | 1.01 | 22.25 | 269 | .02 | .02 | .00 | 56. |
| 1.01 | 10.30 | 126 | .07 | .06 | .00 | 281. | | 1.01 | 22.30 | 270 | .02 | .02 | .00 | 56. |
| 1.01 | 10.35 | 127 | .07 | .06 | .00 | 281. | | 1.01 | 22.35 | 271 | .02 | .02 | .00 | 56. |
| 1.01 | 10.40 | 128 | .07 | .06 | .00 | 281. | | 1.01 | 22.40 | 272 | .02 | .02 | .00 | 56. |
| 1.01 | 10.45 | 129 | .07 | .06 | .00 | 281. | | 1.01 | 22.45 | 273 | .02 | .02 | .00 | 56. |
| 1.01 | 10.50 | 130 | .07 | .06 | .00 | 281. | | 1.01 | 22.50 | 274 | .02 | .02 | .00 | 56. |
| 1.01 | 10.55 | 131 | .07 | .06 | .00 | 281. | | 1.01 | 22.55 | 275 | .02 | .02 | .00 | 56. |
| 1.01 | 11.00 | 132 | .07 | .06 | .00 | 281. | | 1.01 | 23.00 | 276 | .02 | .02 | .00 | 56. |
| 1.01 | 11.05 | 133 | .07 | .06 | .00 | 282. | | 1.01 | 23.05 | 277 | .02 | .02 | .00 | 56. |
| 1.01 | 11.10 | 134 | .07 | .06 | .00 | 282. | | 1.01 | 23.10 | 278 | .02 | .02 | .00 | 56. |
| 1.01 | 11.15 | 135 | .07 | .06 | .00 | 282. | | 1.01 | 23.15 | 279 | .02 | .02 | .00 | 56. |
| 1.01 | 11.20 | 136 | .07 | .06 | .00 | 282. | | 1.01 | 23.20 | 280 | .02 | .02 | .00 | 56. |
| 1.01 | 11.25 | 137 | .07 | .06 | .00 | 282. | | 1.01 | 23.25 | 281 | .02 | .02 | .00 | 56. |
| 1.01 | 11.30 | 138 | .07 | .06 | .00 | 282. | | 1.01 | 23.30 | 282 | .02 | .02 | .00 | 56. |
| 1.01 | 11.35 | 139 | .07 | .06 | .00 | 282. | | 1.01 | 23.35 | 283 | .02 | .02 | .00 | 56. |
| 1.01 | 11.40 | 140 | .07 | .06 | .00 | 282. | | 1.01 | 23.40 | 284 | .02 | .02 | .00 | 56. |
| 1.01 | 11.45 | 141 | .07 | .06 | .00 | 282. | | 1.01 | 23.45 | 285 | .02 | .02 | .00 | 56. |
| 1.01 | 11.50 | 142 | .07 | .06 | .00 | 283. | | 1.01 | 23.50 | 286 | .02 | .02 | .00 | 56. |
| 1.01 | 11.55 | 143 | .07 | .06 | .00 | 283. | | 1.01 | 23.55 | 287 | .02 | .02 | .00 | 56. |
| 1.01 | 12.00 | 144 | .07 | .06 | .00 | 283. | | 1.02 | 0. | 288 | .02 | .02 | .00 | 56. |
| | | | | | | | | | | SUM | 33.80 | 33.12 | .69 | 145539. |
| | | | | | | | | | | | ( 859.)( | 841.)( | 17.)( | 4122.34) |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 4780. | 1591. | 505. | 505. | 145503. |
| CMS | 135. | 45. | 14. | 14. | 4120. |
| INCHES | | 25.96 | 32.98 | 32.98 | 32.98 |
| MM | | 659.51 | 837.70 | 837.70 | 837.70 |
| AC-FT | | 789. | 1002. | 1002. | 1002. |
| THOUS CU M | | 973. | 1236. | 1236. | 1236. |

HYDROGRAPH AT STA LAKE FOR PLAN 1, RTIO 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 1. | 2. | 3. | 4. | 6. | 7. | 8. | 9. | 9. |
| 10. | 10. | 10. | 10. | 10. | 11. | 11. | 11. | 12. | 12. |
| 13. | 13. | 14. | 14. | 15. | 15. | 15. | 16. | 16. | 17. |
| 17. | 18. | 18. | 18. | 19. | 19. | 19. | 20. | 20. | 20. |
| 21. | 21. | 21. | 21. | 22. | 22. | 22. | 22. | 22. | 23. |
| 23. | 23. | 23. | 23. | 24. | 24. | 24. | 24. | 24. | 24. |
| 25. | 25. | 25. | 25. | 25. | 25. | 25. | 25. | 26. | 26. |
| 26. | 26. | 27. | 31. | 39. | 51. | 65. | 78. | 90. | 100. |
| 107. | 112. | 117. | 120. | 123. | 125. | 127. | 128. | 129. | 130. |
| 131. | 132. | 133. | 133. | 134. | 134. | 135. | 135. | 136. | 136. |
| 136. | 136. | 137. | 137. | 137. | 137. | 138. | 138. | 138. | 138. |
| 138. | 139. | 139. | 139. | 139. | 139. | 139. | 139. | 140. | 140. |
| 140. | 140. | 140. | 140. | 140. | 140. | 140. | 140. | 140. | 141. |
| 141. | 141. | 141. | 141. | 141. | 141. | 141. | 141. | 141. | 141. |
| 141. | 141. | 141. | 141. | 146. | 159. | 188. | 231. | 278. | 325. |
| 366. | 398. | 421. | 437. | 450. | 459. | 467. | 476. | 488. | 503. |
| 518. | 533. | 545. | 556. | 563. | 568. | 572. | 575. | 579. | 587. |
| 500. | 619. | [illegible] | [illegible] | | | | | | |

Output Summary
50% PMF Event
Pea Ridge Mine Dam
MO 30473

B8

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

| OPERATION | STATION | AREA | PLAN | RATIOS APPLIED TO FLOWS: RATIO 1 .50 |
|---|---|---|---|---|
| HYDROGRAPH AT | LAKE | .57 | 1 | 2390. |
| | ( | 1.48) | ( | 67.68)( |
| ROUTED TO | DAM | .57 | 1 | 0. |
| | ( | 1.48) | ( | 0. )( |

Output Summary
50% PMF Event
Pea Ridge Mine Dam
MO 30473

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ...............

| | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|---|---|---|---|
| ELEVATION | 873.00 | 912.00 | 908.40 |
| STORAGE | 4213. | 10791. | 10027. |
| OUTFLOW | 0. | 0. | 0. |

| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS |
|---|---|---|---|---|---|---|---|
| .50 | 876.88 | 0. | 4714. | 0. | 0. | 0. | 0. |

Output Summary
50% PMF Event
Pea Ridge Mine Dam
MO 30473

B10

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*************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION        JULY 1978
  LAST MODIFICATION  01 APR 80
*************************************
           A1       PEA RIDGE MINE DAM NO. 30473
           A2       WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB NO. 79C0009
           A3       PROBABLE MAXIMUM FLOW (PMF) ANALYSIS
           B    288       0       5      -0      -0      -0      -0      -0      -0      -0
           B1     5
           J      1       1       1
           J      1.
           K      0    LAKE                                      1
           K1       INFLOW HYDROGRAPH COMPUTATIONS
           M      1       2     .57                      1.0
           P      0      26     102     120     130
           T                                                    -1     -92             .33
           W2           .4
           X     -1    -.05       5
           K      1     DAM
           K1       FLOOD ROUTING AND OVERTOPPING ANALYSIS
           Y                              1       1
           Y1     1                                          -875.0
           $A    0.    33.7    61.0   100.0   140.0   185.0   240.0
           $E 800.0   820.0   840.0   860.0   880.0   900.0   920.0
           $$912.00      0.     3.0     1.5
           $D 908.4     2.6     1.5
           $L    0.   370.0   610.0   950.0  1000.0  1080.0  1360.0  1384.0
           $V 908.4   908.6   909.0   909.4   910.0   911.0   912.0   912.4
           K     99
```

Input Data
100% PMF Event
Pea Ridge Mine Dam
MO  30473

B11

Output Summary
100% PMF Event
Pea Ridge Mine Dam
MO 30473

B12

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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION        JULY 1978
  LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE: 20 AUG 80
     TIME: 12.52.28

                    PEA RIDGE MINE DAM NO. 30473
                    WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB NO. 79CH009
                    PROBABLE MAXIMUM FLOW (PMF) ANALYSIS

                              JOB SPECIFICATION
      NQ      NHR     NMIN     IDAY      IHR     IMIN    METRC     IPLT     IPRT    NSTAN
     288        0        5       -0       -0       -0       -0       -0       -0       -0
                              JOPER      NWT    LROPT    TRACE
                                  5       -0       -0       -0

                         MULTI-PLAN ANALYSES TO BE PERFORMED
                               NPLAN= 1 NRTIO= 1 LRTIO= 1
     RTIOS=    1.00

  **********          **********          **********          **********          **********

                           SUB-AREA RUNOFF COMPUTATION

                 INFLOW HYDROGRAPH COMPUTATIONS

                    ISTAQ    ICOMP    IECON    ITAPE     JPLT     JPRT    INAME   ISTAGE    IAUTO
                     LAKE        0       -0       -0       -0       -0        1       -0       -0

                                     HYDROGRAPH DATA
     IHYDG     IUHG    TAREA     SNAP    TRSDA    TRSPC    RATIO    ISNOW    ISAME    LOCAL
         1        2      .57      -0.      .57     1.00      -0.       -0       -0       -0

                                      PRECIP DATA
              SPFE      PMS       R6      R12      R24      R48      R72      R96
                0.    26.00   102.00   120.00   130.00      -0.      -0.      -0.

                                       LOSS DATA
    LROPT    STRKR    DLTKR    RTIOL    ERAIN    STRKS    RTIOK    STRTL    CNSTL    ALSMX    RTIMP
       -0      -0.      -0.     1.00      -0.      -0.     1.00    -1.00   -92.00      -0.      .33

     CURVE NO =  -92.00  WETNESS =   -1.00  EFFECT CN =   92.00

                                UNIT HYDROGRAPH DATA
                             TC= -0.       LAG=   .40

                                    RECESSION DATA
                        STRTQ=    -1.00     QRCSN=     -.05     RTIOR= 5.00

     UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC=   -0.   HOURS, LAG=    .40  VOL= 1.00
     57.      176.      371.      549.      620.      606.     [illegible]
```

UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .40 VOL= 1.00

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 57. | 176. | 371. | 549. | 620. | 605. | 526. | 417. | 288. | 211. |
| 157. | 117. | 85. | 63. | 46. | 33. | 25. | 18. | 13. | 10. |
| 7. | 6. | 4. | 3. | 2. | 1. | | | | |

0

END-OF-PERIOD FLOW

| MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q | MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | .05 | 1 | .01 | .00 | .01 | 1. | 1.01 | 12.05 | 145 | .22 | .22 | .00 | 252. |
| 1.01 | .10 | 2 | .01 | .00 | .01 | 2. | 1.01 | 12.10 | 146 | .22 | .22 | .00 | 315. |
| 1.01 | .15 | 3 | .01 | .00 | .01 | 3. | 1.01 | 12.15 | 147 | .22 | .22 | .00 | 376. |
| 1.01 | .20 | 4 | .01 | .00 | .01 | 6. | 1.01 | 12.20 | 148 | .22 | .22 | .00 | 441. |
| 1.01 | .25 | 5 | .01 | .00 | .01 | 9. | 1.01 | 12.25 | 149 | .22 | .22 | .00 | 557. |
| 1.01 | .30 | 6 | .01 | .00 | .01 | 12. | 1.01 | 12.30 | 150 | .22 | .22 | .00 | 651. |
| 1.01 | .35 | 7 | .01 | .00 | .01 | 14. | 1.01 | 12.35 | 151 | .22 | .22 | .00 | 732. |
| 1.01 | .40 | 8 | .01 | .00 | .01 | 16. | 1.01 | 12.40 | 152 | .22 | .22 | .00 | 797. |
| 1.01 | .45 | 9 | .01 | .00 | .01 | 17. | 1.01 | 12.45 | 153 | .22 | .22 | .00 | 842. |
| 1.01 | .50 | 10 | .01 | .00 | .01 | 18. | 1.01 | 12.50 | 154 | .22 | .22 | .00 | 875. |
| 1.01 | .55 | 11 | .01 | .00 | .01 | 19. | 1.01 | 12.55 | 155 | .22 | .22 | .00 | 899. |
| 1.01 | 1.00 | 12 | .01 | .00 | .01 | 20. | 1.01 | 13.00 | 156 | .22 | .22 | .00 | 918. |
| 1.01 | 1.05 | 13 | .01 | .00 | .01 | 20. | 1.01 | 13.05 | 157 | .27 | .26 | .00 | 934. |
| 1.01 | 1.10 | 14 | .01 | .01 | .01 | 20. | 1.01 | 13.10 | 158 | .27 | .26 | .00 | 952. |
| 1.01 | 1.15 | 15 | .01 | .01 | .01 | 21. | 1.01 | 13.15 | 159 | .27 | .26 | .00 | 975. |
| 1.01 | 1.20 | 16 | .01 | .01 | .01 | 21. | 1.01 | 13.20 | 160 | .27 | .26 | .00 | 1005. |
| 1.01 | 1.25 | 17 | .01 | .01 | .01 | 22. | 1.01 | 13.25 | 161 | .27 | .26 | .00 | 1037. |
| 1.01 | 1.30 | 18 | .01 | .01 | .01 | 22. | 1.01 | 13.30 | 162 | .27 | .26 | .00 | 1066. |
| 1.01 | 1.35 | 19 | .01 | .01 | .01 | 23. | 1.01 | 13.35 | 163 | .27 | .26 | .00 | 1092. |
| 1.01 | 1.40 | 20 | .01 | .01 | .01 | 24. | 1.01 | 13.40 | 164 | .27 | .26 | .00 | 1112. |
| 1.01 | 1.45 | 21 | .01 | .01 | .01 | 25. | 1.01 | 13.45 | 165 | .27 | .26 | .00 | 1126. |
| 1.01 | 1.50 | 22 | .01 | .01 | .01 | 26. | 1.01 | 13.50 | 166 | .27 | .26 | .00 | 1137. |
| 1.01 | 1.55 | 23 | .01 | .01 | .01 | 27. | 1.01 | 13.55 | 167 | .27 | .26 | .00 | 1144. |
| 1.01 | 2.00 | 24 | .01 | .01 | .01 | 28. | 1.01 | 14.00 | 168 | .27 | .26 | .00 | 1150. |
| 1.01 | 2.05 | 25 | .01 | .01 | .01 | 29. | 1.01 | 14.05 | 169 | .33 | .33 | .00 | 1158. |
| 1.01 | 2.10 | 26 | .01 | .01 | .01 | 30. | 1.01 | 14.10 | 170 | .33 | .33 | .00 | 1173. |
| 1.01 | 2.15 | 27 | .01 | .01 | .01 | 31. | 1.01 | 14.15 | 171 | .33 | .33 | .00 | 1200. |
| 1.01 | 2.20 | 28 | .01 | .01 | .01 | 32. | 1.01 | 14.20 | 172 | .33 | .33 | .00 | 1238. |
| 1.01 | 2.25 | 29 | .01 | .01 | .01 | 33. | 1.01 | 14.25 | 173 | .33 | .33 | .00 | 1280. |
| 1.01 | 2.30 | 30 | .01 | .01 | .01 | 34. | 1.01 | 14.30 | 174 | .33 | .33 | .00 | 1321. |
| 1.01 | 2.35 | 31 | .01 | .01 | .01 | 34. | 1.01 | 14.35 | 175 | .33 | .33 | .00 | 1357. |
| 1.01 | 2.40 | 32 | .01 | .01 | .01 | 35. | 1.01 | 14.40 | 176 | .33 | .33 | .00 | 1385. |
| 1.01 | 2.45 | 33 | .01 | .01 | .01 | 36. | 1.01 | 14.45 | 177 | .33 | .33 | .00 | 1405. |
| 1.01 | 2.50 | 34 | .01 | .01 | .01 | 37. | 1.01 | 14.50 | 178 | .33 | .33 | .00 | 1415. |
| 1.01 | 2.55 | 35 | .01 | .01 | .01 | 37. | 1.01 | 14.55 | 179 | .33 | .33 | .00 | 1430. |
| 1.01 | 3.00 | 36 | .01 | .01 | .01 | 38. | 1.01 | 15.00 | 180 | .33 | .33 | .00 | 1438. |
| 1.01 | 3.05 | 37 | .01 | .01 | .00 | 39. | 1.01 | 15.05 | 181 | .20 | .20 | .00 | 1436. |
| 1.01 | 3.10 | 38 | .01 | .01 | .00 | 39. | 1.01 | 15.10 | 182 | .40 | .40 | .00 | 1429. |
| 1.01 | 3.15 | 39 | .01 | .01 | .00 | 40. | 1.01 | 15.15 | 183 | .40 | .40 | .00 | 1420. |
| 1.01 | 3.20 | 40 | .01 | .01 | .00 | 40. | 1.01 | 15.20 | 184 | .60 | .60 | .00 | 1437. |
| 1.01 | 3.25 | 41 | .01 | .01 | .00 | 41. | 1.01 | 15.25 | 185 | .71 | .70 | .00 | 1510. |
| 1.01 | 3.30 | 42 | .01 | .01 | .00 | 42. | 1.01 | 15.30 | 186 | 1.71 | 1.71 | .00 | 1708. |
| 1.01 | 3.35 | 43 | .01 | .01 | .00 | 42. | 1.01 | 15.35 | 187 | 2.82 | 2.82 | .00 | 2151. |
| 1.01 | 3.40 | 44 | .01 | .01 | .00 | 43. | 1.01 | 15.40 | 188 | 1.11 | 1.11 | .00 | 2859. |
| 1.01 | 3.45 | 45 | .01 | .01 | .00 | 43. | 1.01 | 15.45 | 189 | .71 | .70 | .00 | 3725. |
| 1.01 | 3.50 | 46 | .01 | .01 | .00 | 44. | 1.01 | 15.50 | 190 | .60 | .60 | .00 | 4443. |
| 1.01 | 3.55 | 47 | .01 | .01 | .00 | 44. | 1.01 | 15.55 | 191 | .40 | .40 | .00 | 4780. |
| 1.01 | 4.00 | 48 | .01 | .01 | .00 | 44. | 1.01 | 16.00 | 192 | .40 | .40 | .00 | 4742. |
| 1.01 | 4.05 | 49 | .01 | .01 | .00 | 45. | 1.01 | 16.05 | 193 | .31 | .31 | .00 | 4407. |
| 1.01 | 4.10 | 50 | .01 | .01 | .00 | 45. | 1.01 | 16.10 | 194 | .31 | .31 | .00 | 3888. |
| 1.01 | 4.15 | 51 | .01 | .01 | .00 | 46. | 1.01 | 16.15 | 195 | .31 | .31 | .00 | 3319. |
| 1.01 | 4.20 | 52 | .01 | .01 | .00 | 46. | 1.01 | 16.20 | 196 | .31 | .31 | .00 | 2858. |
| 1.01 | 4.25 | 53 | .01 | .01 | .00 | 46. | 1.01 | 16.25 | 197 | .31 | .31 | .00 | 2453. |
| 1.01 | 4.30 | 54 | .01 | .01 | .00 | 47. | 1.01 | 16.30 | 198 | .31 | .31 | .00 | 2262. |
| 1.01 | 4.35 | 55 | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | |

Output Summary
100% PMF Event
Pea Ridge Mine Dam
MO 30473

B13

Output Summary
100% PMF Event
Pea Ridge Mine Dam
MO 30473

B14

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | 4.10 | 50 | .01 | .01 | .00 | 45. | 1.01 | 16.10 | 194 | .31 | .31 | .00 | [illegible] |
| 1.01 | 4.15 | 51 | .01 | .01 | .00 | 46. | 1.01 | 16.15 | 195 | .31 | .31 | .00 | 3319. |
| 1.01 | 4.20 | 52 | .01 | .01 | .00 | 46. | 1.01 | 16.20 | 196 | .31 | .31 | .00 | 2858. |
| 1.01 | 4.25 | 53 | .01 | .01 | .00 | 46. | 1.01 | 16.25 | 197 | .31 | .31 | .00 | 2453. |
| 1.01 | 4.30 | 54 | .01 | .01 | .00 | 47. | 1.01 | 16.30 | 198 | .31 | .31 | .00 | 2202. |
| 1.01 | 4.35 | 55 | .01 | .01 | .00 | 47. | 1.01 | 16.35 | 199 | .31 | .31 | .00 | 1981. |
| 1.01 | 4.40 | 56 | .01 | .01 | .00 | 47. | 1.01 | 16.40 | 200 | .31 | .31 | .00 | 1816. |
| 1.01 | 4.45 | 57 | .01 | .01 | .00 | 48. | 1.01 | 16.45 | 201 | .31 | .31 | .00 | 1656. |
| 1.01 | 4.50 | 58 | .01 | .01 | .00 | 48. | 1.01 | 16.50 | 202 | .31 | .31 | .00 | 1607. |
| 1.01 | 4.55 | 59 | .01 | .01 | .00 | 48. | 1.01 | 16.55 | 203 | .31 | .31 | .00 | 1543. |
| 1.01 | 5.00 | 60 | .01 | .01 | .00 | 49. | 1.01 | 17.00 | 204 | .31 | .31 | .00 | 1456. |
| 1.01 | 5.05 | 61 | .01 | .01 | .00 | 49. | 1.01 | 17.05 | 205 | .24 | .24 | .00 | 1457. |
| 1.01 | 5.10 | 62 | .01 | .01 | .00 | 49. | 1.01 | 17.10 | 206 | .24 | .24 | .00 | 1420. |
| 1.01 | 5.15 | 63 | .01 | .01 | .00 | 50. | 1.01 | 17.15 | 207 | .24 | .24 | .00 | 1377. |
| 1.01 | 5.20 | 64 | .01 | .01 | .00 | 50. | 1.01 | 17.20 | 208 | .24 | .24 | .00 | 1328. |
| 1.01 | 5.25 | 65 | .01 | .01 | .00 | 50. | 1.01 | 17.25 | 209 | .24 | .24 | .00 | 1276. |
| 1.01 | 5.30 | 66 | .01 | .01 | .00 | 50. | 1.01 | 17.30 | 210 | .24 | .24 | .00 | 1227. |
| 1.01 | 5.35 | 67 | .01 | .01 | .00 | 51. | 1.01 | 17.35 | 211 | .24 | .24 | .00 | 1184. |
| 1.01 | 5.40 | 68 | .01 | .01 | .00 | 51. | 1.01 | 17.40 | 212 | .24 | .24 | .00 | 1151. |
| 1.01 | 5.45 | 69 | .01 | .01 | .00 | 51. | 1.01 | 17.45 | 213 | .24 | .24 | .00 | 1128. |
| 1.01 | 5.50 | 70 | .01 | .01 | .00 | 51. | 1.01 | 17.50 | 214 | .24 | .24 | .00 | 1119. |
| 1.01 | 5.55 | 71 | .01 | .01 | .00 | 52. | 1.01 | 17.55 | 215 | .24 | .24 | .00 | 1101. |
| 1.01 | 6.00 | 72 | .01 | .01 | .00 | 52. | 1.01 | 18.00 | 216 | .24 | .24 | .00 | 1093. |
| 1.01 | 6.05 | 73 | .07 | .05 | .01 | 54. | 1.01 | 18.05 | 217 | .02 | .02 | .00 | 1079. |
| 1.01 | 6.10 | 74 | .07 | .05 | .01 | 62. | 1.01 | 18.10 | 218 | .02 | .02 | .00 | 1031. |
| 1.01 | 6.15 | 75 | .07 | .06 | .01 | 78. | 1.01 | 18.15 | 219 | .02 | .02 | .00 | 946. |
| 1.01 | 6.20 | 76 | .07 | .06 | .01 | 102. | 1.01 | 18.20 | 220 | .02 | .02 | .00 | 822. |
| 1.01 | 6.25 | 77 | .07 | .06 | .01 | 129. | 1.01 | 18.25 | 221 | .02 | .02 | .00 | 684. |
| 1.01 | 6.30 | 78 | .07 | .06 | .01 | 156. | 1.01 | 18.30 | 222 | .02 | .02 | .00 | 548. |
| 1.01 | 6.35 | 79 | .07 | .06 | .01 | 180. | 1.01 | 18.35 | 223 | .02 | .02 | .00 | 431. |
| 1.01 | 6.40 | 80 | .07 | .05 | .01 | 200. | 1.01 | 18.40 | 224 | .02 | .02 | .00 | 338. |
| 1.01 | 6.45 | 81 | .07 | .06 | .01 | 214. | 1.01 | 18.45 | 225 | .02 | .02 | .00 | 274. |
| 1.01 | 6.50 | 82 | .07 | .06 | .01 | 225. | 1.01 | 18.50 | 226 | .02 | .02 | .00 | 230. |
| 1.01 | 6.55 | 83 | .07 | .06 | .01 | 233. | 1.01 | 18.55 | 227 | .02 | .02 | .00 | 196. |
| 1.01 | 7.00 | 84 | .07 | .06 | .01 | 240. | 1.01 | 19.00 | 228 | .02 | .02 | .00 | 167. |
| 1.01 | 7.05 | 85 | .07 | .06 | .01 | 246. | 1.01 | 19.05 | 229 | .02 | .02 | .00 | 147. |
| 1.01 | 7.10 | 86 | .07 | .06 | .00 | 250. | 1.01 | 19.10 | 230 | .02 | .02 | .00 | 133. |
| 1.01 | 7.15 | 87 | .07 | .06 | .00 | 253. | 1.01 | 19.15 | 231 | .02 | .02 | .00 | 123. |
| 1.01 | 7.20 | 88 | .07 | .06 | .00 | 256. | 1.01 | 19.20 | 232 | .02 | .02 | .00 | 115. |
| 1.01 | 7.25 | 89 | .07 | .06 | .00 | 259. | 1.01 | 19.25 | 233 | .02 | .02 | .00 | 110. |
| 1.01 | 7.30 | 90 | .07 | .06 | .00 | 261. | 1.01 | 19.30 | 234 | .02 | .02 | .00 | 106. |
| 1.01 | 7.35 | 91 | .07 | .06 | .00 | 263. | 1.01 | 19.35 | 235 | .02 | .02 | .00 | 103. |
| 1.01 | 7.40 | 92 | .07 | .06 | .00 | 264. | 1.01 | 19.40 | 236 | .02 | .02 | .00 | 101. |
| 1.01 | 7.45 | 93 | .07 | .06 | .00 | 265. | 1.01 | 19.45 | 237 | .02 | .02 | .00 | 99. |
| 1.01 | 7.50 | 94 | .07 | .06 | .00 | 267. | 1.01 | 19.50 | 238 | .02 | .02 | .00 | 98. |
| 1.01 | 7.55 | 95 | .07 | .06 | .00 | 268. | 1.01 | 19.55 | 239 | .02 | .02 | .00 | 97. |
| 1.01 | 8.00 | 96 | .07 | .06 | .00 | 269. | 1.01 | 20.00 | 240 | .02 | .02 | .00 | 96. |
| 1.01 | 8.05 | 97 | .07 | .06 | .00 | 270. | 1.01 | 20.05 | 241 | .02 | .02 | .00 | 96. |
| 1.01 | 8.10 | 98 | .07 | .06 | .00 | 270. | 1.01 | 20.10 | 242 | .02 | .02 | .00 | 96. |
| 1.01 | 8.15 | 99 | .07 | .06 | .00 | 271. | 1.01 | 20.15 | 243 | .02 | .02 | .00 | 96. |
| 1.01 | 8.20 | 100 | .07 | .06 | .00 | 272. | 1.01 | 20.20 | 244 | .02 | .02 | .00 | 96. |
| 1.01 | 8.25 | 101 | .07 | .05 | .00 | 272. | 1.01 | 20.25 | 245 | .02 | .02 | .00 | 96. |
| 1.01 | 8.30 | 102 | .07 | .06 | .00 | 273. | 1.01 | 20.30 | 246 | .02 | .02 | .00 | 96. |
| 1.01 | 8.35 | 103 | .07 | .06 | .00 | 274. | 1.01 | 20.35 | 247 | .02 | .02 | .00 | 96. |
| 1.01 | 8.40 | 104 | .07 | .06 | .00 | 274. | 1.01 | 20.40 | 248 | .02 | .02 | .00 | 96. |
| 1.01 | 8.45 | 105 | .07 | .06 | .00 | 275. | 1.01 | 20.45 | 249 | .02 | .02 | .00 | 96. |
| 1.01 | 8.50 | 106 | .07 | .06 | .00 | 275. | 1.01 | 20.50 | 250 | .02 | .02 | .00 | 96. |
| 1.01 | 8.55 | 107 | .07 | .06 | .00 | 275. | 1.01 | 20.55 | 251 | .02 | .02 | .00 | 96. |
| 1.01 | 9.00 | 108 | .07 | .06 | .00 | 276. | 1.01 | 21.00 | 252 | .02 | .02 | .00 | 96. |
| 1.01 | 9.05 | 109 | .07 | .06 | .00 | 276. | 1.01 | 21.05 | 253 | .02 | .02 | .00 | 96. |
| 1.01 | 9.10 | 110 | .07 | .06 | .00 | 277. | 1.01 | 21.10 | 254 | .02 | .02 | .00 | 96. |
| 1.01 | 9.15 | 111 | .07 | .06 | .00 | 277. | 1.01 | 21.15 | 255 | .02 | .02 | .00 | 96. |
| 1.01 | 9.20 | 112 | .07 | .06 | .00 | 277. | 1.01 | 21.20 | 256 | .02 | .02 | .00 | 96. |
| 1.01 | 9.25 | 113 | .07 | .06 | .00 | 278. | 1.01 | 21.25 | 257 | .02 | .02 | .00 | [illegible] |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | .07 | .06 | .00 | 275. | 1.01 | 20.50 | 250 | .02 | .02 | .00 | 56. |
| 1.01 | 8.55 | 107 | .07 | .06 | .00 | 275. | 1.01 | 20.55 | 251 | .02 | .02 | .00 | 56. |
| 1.01 | 9.00 | 108 | .07 | .06 | .00 | 276. | 1.01 | 21.00 | 252 | .02 | .02 | .00 | 56. |
| 1.01 | 9.05 | 109 | .07 | .06 | .00 | 276. | 1.01 | 21.05 | 253 | .02 | .02 | .00 | 56. |
| 1.01 | 9.10 | 110 | .07 | .06 | .00 | 277. | 1.01 | 21.10 | 254 | .02 | .02 | .00 | 56. |
| 1.01 | 9.15 | 111 | .07 | .06 | .00 | 277. | 1.01 | 21.15 | 255 | .02 | .02 | .00 | 56. |
| 1.01 | 9.20 | 112 | .07 | .06 | .00 | 277. | 1.01 | 21.20 | 256 | .02 | .02 | .00 | 56. |
| 1.01 | 9.25 | 113 | .07 | .06 | .00 | 278. | 1.01 | 21.25 | 257 | .02 | .02 | .00 | 56. |
| 1.01 | 9.30 | 114 | .07 | .06 | .00 | 278. | 1.01 | 21.30 | 258 | .02 | .02 | .00 | 56. |
| 1.01 | 9.35 | 115 | .07 | .06 | .00 | 278. | 1.01 | 21.35 | 259 | .02 | .02 | .00 | 56. |
| 1.01 | 9.40 | 116 | .07 | .06 | .00 | 278. | 1.01 | 21.40 | 260 | .02 | .02 | .00 | 56. |
| 1.01 | 9.45 | 117 | .07 | .06 | .00 | 279. | 1.01 | 21.45 | 261 | .02 | .02 | .00 | 56. |
| 1.01 | 9.50 | 118 | .07 | .06 | .00 | 279. | 1.01 | 21.50 | 262 | .02 | .02 | .00 | 56. |
| 1.01 | 9.55 | 119 | .07 | .06 | .00 | 279. | 1.01 | 21.55 | 263 | .02 | .02 | .00 | 56. |
| 1.01 | 10.00 | 120 | .07 | .06 | .00 | 279. | 1.01 | 22.00 | 264 | .02 | .02 | .00 | 56. |
| 1.01 | 10.05 | 121 | .07 | .06 | .00 | 280. | 1.01 | 22.05 | 265 | .02 | .02 | .00 | 56. |
| 1.01 | 10.10 | 122 | .07 | .06 | .00 | 280. | 1.01 | 22.10 | 266 | .02 | .02 | .00 | 56. |
| 1.01 | 10.15 | 123 | .07 | .06 | .00 | 280. | 1.01 | 22.15 | 267 | .02 | .02 | .00 | 56. |
| 1.01 | 10.20 | 124 | .07 | .06 | .00 | 280. | 1.01 | 22.20 | 268 | .02 | .02 | .00 | 56. |
| 1.01 | 10.25 | 125 | .07 | .06 | .00 | 280. | 1.01 | 22.25 | 269 | .02 | .02 | .00 | 56. |
| 1.01 | 10.30 | 126 | .07 | .06 | .00 | 281. | 1.01 | 22.30 | 270 | .02 | .02 | .00 | 56. |
| 1.01 | 10.35 | 127 | .07 | .06 | .00 | 281. | 1.01 | 22.35 | 271 | .02 | .02 | .00 | 56. |
| 1.01 | 10.40 | 128 | .07 | .06 | .00 | 281. | 1.01 | 22.40 | 272 | .02 | .02 | .00 | 56. |
| 1.01 | 10.45 | 129 | .07 | .06 | .00 | 281. | 1.01 | 22.45 | 273 | .02 | .02 | .00 | 56. |
| 1.01 | 10.50 | 130 | .07 | .06 | .00 | 281. | 1.01 | 22.50 | 274 | .02 | .02 | .00 | 56. |
| 1.01 | 10.55 | 131 | .07 | .06 | .00 | 281. | 1.01 | 22.55 | 275 | .02 | .02 | .00 | 56. |
| 1.01 | 11.00 | 132 | .07 | .06 | .00 | 281. | 1.01 | 23.00 | 276 | .02 | .02 | .00 | 56. |
| 1.01 | 11.05 | 133 | .07 | .06 | .00 | 282. | 1.01 | 23.05 | 277 | .02 | .02 | .00 | 56. |
| 1.01 | 11.10 | 134 | .07 | .06 | .00 | 282. | 1.01 | 23.10 | 278 | .02 | .02 | .00 | 56. |
| 1.01 | 11.15 | 135 | .07 | .06 | .00 | 282. | 1.01 | 23.15 | 279 | .02 | .02 | .00 | 56. |
| 1.01 | 11.20 | 136 | .07 | .06 | .00 | 282. | 1.01 | 23.20 | 280 | .02 | .02 | .00 | 56. |
| 1.01 | 11.25 | 137 | .07 | .06 | .00 | 282. | 1.01 | 23.25 | 281 | .02 | .02 | .00 | 56. |
| 1.01 | 11.30 | 138 | .07 | .06 | .00 | 282. | 1.01 | 23.30 | 282 | .02 | .02 | .00 | 56. |
| 1.01 | 11.35 | 139 | .07 | .06 | .00 | 282. | 1.01 | 23.35 | 283 | .02 | .02 | .00 | 56. |
| 1.01 | 11.40 | 140 | .07 | .06 | .00 | 282. | 1.01 | 23.40 | 284 | .02 | .02 | .00 | 56. |
| 1.01 | 11.45 | 141 | .07 | .06 | .00 | 282. | 1.01 | 23.45 | 285 | .02 | .02 | .00 | 56. |
| 1.01 | 11.50 | 142 | .07 | .06 | .00 | 283. | 1.01 | 23.50 | 286 | .02 | .02 | .00 | 56. |
| 1.01 | 11.55 | 143 | .07 | .06 | .00 | 283. | 1.01 | 23.55 | 287 | .02 | .02 | .00 | 56. |
| 1.01 | 12.00 | 144 | .07 | .06 | .00 | 283. | 1.02 | 0. | 288 | .02 | .02 | .00 | 56. |
| | | | | | | | | | SUM | 33.80 | 33.12 | .68 | 145575. |
| | | | | | | | | | | ( 859.)( | 841.)( | 17.)( | 4122.34) |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 4780. | 1591. | 505. | 505. | 145503. |
| CMS | 135. | 45. | 14. | 14. | 4120. |
| INCHES | | 25.96 | 32.98 | 32.98 | 32.98 |
| MM | | 659.51 | 837.70 | 837.70 | 837.70 |
| AC-FT | | 789. | 1002. | 1002. | 1002. |
| THOUS CU M | | 973. | 1236. | 1236. | 1236. |

HYDROGRAPH AT STA LAKE FOR PLAN 1, RTIO 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 2. | 3. | 6. | 9. | 12. | 14. | 16. | 17. | 18. |
| 19. | 20. | 20. | 20. | 21. | 21. | 22. | 22. | 23. | 24. |
| 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. | 33. | 34. |
| 34. | 35. | 36. | 37. | 37. | 38. | 39. | 39. | 40. | 40. |
| 41. | 42. | 42. | 43. | 43. | 44. | 44. | 44. | 45. | 45. |
| 46. | 46. | 46. | 47. | 47. | 47. | 48. | 48. | 48. | 49. |
| 49. | 49. | 50. | 50. | 50. | 50. | 51. | 51. | 51. | 51. |
| 52. | 52. | 54. | 62. | 78. | 102. | 129. | 156. | 180. | 200. |
| 214. | 225. | 233. | 240. | 246. | 250. | 253. | 256. | 259. | 261. |
| 263. | 264. | 265. | 267. | 268. | 269. | 270. | 270. | 271. | 272. |
| [illegible] | [illegible] | [illegible] | [illegible] | | | | | | |

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**Output Summary**
**100% PMF Event**
**Pea Ridge Mine Dam**
**MO 30473**

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ...............

| | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|---|---|---|---|
| ELEVATION | 875.00 | 912.00 | 909.40 |
| STORAGE | 4468. | 10791. | 10027. |
| OUTFLOW | 0. | 0. | 0. |

| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS |
|---|---|---|---|---|---|---|---|
| 1.00 | 882.31 | 0. | 5470. | 0. | 0. | 0. | 0. |

Output Summary
100% PMF Event
Pea Ridge Mine Dam
MO 30473

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PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

| OPERATION | STATION | AREA | PLAN | RATIOS APPLIED TO FLOWS<br>RATIO 1<br>1.00 |
|---|---|---|---|---|
| HYDROGRAPH AT | LAKE | .57<br>( 1.48) | 1<br>( | 4780.<br>135.36)( |
| ROUTED TO | DAM | .57<br>( 1.48) | 1<br>( | 0.<br>0. )( |

Output Summary
100% PMF Event
Pea Ridge Mine Dam
MO 30473

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# APPENDIX C

Design Report for
Pea Ridge Tailings Dam
Meramec Mining Company
Sullivan, Missouri

Project No. 61-109

BETHLEHEM STEEL COMPANY
BETHLEHEM, PENNSYLVANIA

# PEA RIDGE TAILINGS DAM
# MERAMEC MINING COMPANY
# SULLIVAN, MISSOURI

E. D'APPOLONIA ASSOCIATES
CONSULTING ENGINEERS
PITTSBURGH, PENNSYLVANIA

OCTOBER, 1962

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PEA RIDGE TAILINGS DAM
MERAMEC MINING COMPANY
SULLIVAN, MISSOURI

## INTRODUCTION

There have been several modifications in the design of the Pea Ridge tailings dam consistent with conditions exposed in excavations for the first phase construction of the dam. Originally it was planned to construct the tailings dam of either residual soil selected from excavations for the base of the dam and/or from borrow areas adjacent to the dam. In our report to Bethlehem dated March 31, 1961, Drawings M3 and M4 showed sections for the proposed earth and rock fill dams. Based on data given to us by Bethlehem preliminary cost studies had disclosed that the earth fill dam was more economical than the rock fill structure. Later unit cost estimates procured by Bethlehem revealed that the rock could be placed in the dam for approximately $.60 per cubic yard. This meant that the cost of the earth and rock fill dams was about the same.

It was then suggested that further design of the tailings dam be foregone until unequivocal data were obtained on the unit costs for earth and rock fill. Consideration was also given to the use of mine rock for the construction of the dam. It was originally planned not to use the mine rock as it appeared to have a value as aggregate.

Solution Channels. Our report of March 21, 1961, included a general evaluation and interpretation of the electrical resistivity surveys that were made at the dam site. These data supported earlier statements made by the geologists, W. W. Weigel, J. A. Emery and others, of the existence of solution channels in the dolomite formations. There were two significant problems associated with these channels:

(1) If the channel extended beneath the impervious core there was the possibility of a piping failure.

(2) If the solution channels were large and void of material there was the possibility of subsidence with increased weight of overburden and possible piping and stability failure of the dam.

Recognizing the potential hazards, it was recommended that all of the overburden - residual soil and weathered rock - beneath the base of the dam be removed to the firm rock surface. In this manner the solution channels that carried through to the top of the rock surface would be exposed and proper steps could be taken during construction to seal them against possible piping and collapse. In addition, the removal of the residual soil beneath the dam eliminated potential slope failures associated with pore-water pressures that could develop at the interface between the top of the firm rock surface and the base of the residual soil by the water entering the solution channels and fractures in the reservoir and escaping through these openings into the interface. Near the toe of the dam where the weight of superimposed overburden would be light the pore-water pressures could have such intensity as to reduce the shearing resistance of the residual soil to a state of failure. And accordingly it follows, that providing a free access of escape into the pervious sections of the dam the stability of the downstream slope is assured. Drains as shown on Drawing M3 were considered in the design of the earth dam.

Considering the difficulty and cost that would be entailed in properly exploring the extent and direction of the solution channels discovered by electrical resistivity surveys it was decided to forego all further subsurface explorations to the time that construction was underway and the rock surface had been exposed at least for the first phase. Hence, no additional borings other than those described and submitted to us by Bethlehem in correspondence dated February 17, 1961, were drilled.

<u>Cobber Reject Dam</u>. Little engineering work was done on the design of the Pea Ridge tailings dam between the period of March and October, 1961. In a telephone conversation with D. S. Lyons on October 2, 1961, we were asked to proceed with the design of a tailings dam in which the cobber reject rock having particles ranging from -5/8 to +1/4 inch would be used to form the major portion of the dam and the impervious core would be residual soil taken from the base of the dam and if not suitable from borrow areas adjacent to the dam. For the first phase construction, that is the dam with breast elevation approximately 810, it was to consist of mine rock - hard ryholite porphyry - taken from the development of the shaft and entries to the ore body. It was our understanding that this mine rock would be composed primarily of large gravel and cobble sizes. Some 85,000 cubic yards of material were available for first phase construction.

It was further planned that riprap would be quarried dolomite and that large dolomite rock - nine inch plus - would be used in the trench

excavated in the valley as a conduit for storm water runoff. The tailings dam of cobber reject and mine rock was planned without a spillway. Storm water would be passed through the pervious fill into the rock trench in the valley floor to a discharge point below the toe of the dam.

It was calculated that the critical design storm for the first phase construction could be contained partly in storage in the reservoir and the remainder gradually discharged through the pervious mine rock fill. It had been estimated that peak discharges through the fill would be about 200 cubic feet per second of which 150 would be carried by the trench and the remainder would be flowing as a thin sheet along the valley bottom above the trench. The velocities with which the water emanated at the toe of the rock fill and from the cobber reject for subsequent phases of construction were not sufficiently high to disturb the toe. The computed maximum rise of storm water in the reservoir was about two feet. A freeboard of five feet as shown on Drawing M17 was provided. The maximum velocity of flow in the rock trench was one and one-half feet per second.

The construction of the tailings dam in accordance with Drawing M17 required the complete removal of residual soil beneath the whole of the base to be occupied by the dam and the construction of a trench 40 feet in width and five feet deep into the dolomites along the valley bottom. This trench as mentioned earlier was to be filled with quarried rock plus nine inches in diameter and the first phase construction was to be composed of a large rock taken from the workings in the development of the mine. It was necessary to remove all of the residual soil beneath the

dam in order to avoid erosion and silting of the trench by the storm water that would flow along the abutment slopes into the trench during periods of flooding. It had been planned to discharge the storm water through the spillway formed by the full length of dam between abutments for each stage of construction.

On November 3, 1961, Drawing M17, showing plan, section and excavations, and Drawing M18, showing graphical relations giving the quantities of material required for the construction of the tailings dam and the volume of the basin, were submitted in the report Pea Ridge Tailings Dam along with the Specifications for the Construction of Pea Ridge Tailings Dam.

Field Inspection and Design Changes. Following stripping of the area and the removal of the residual soil to the firm rock surface beneath that portion of the dam to be occupied by phase one the writer inspected the site on May 31, 1962, and again on July 24, 1962. He found conditions different than those anticipated, primarily in the fact that the solution channels which had been discussed in detail in earlier reports were large but fortunately, filled with a relatively impervious colluvial material composed of partially consolidated clay, chert, tripoli and dolomite. The crevice in the south abutment as shown in the construction photographs submitted to us on September 4 and September 6, 1962, is about four feet in width and its depth is not known. It occurs in the Eminence and the surface of the ledge is at approximately elevation 790 the contact between the Gasconade and Eminence formations. From the

writer's inspection of numerous exposures of both formations at the dam, pellet plant and clarifier, he concluded that the large solution channels were filled and that piping would not be a problem provided the upper portions of the colluvial filling were excavated and well compacted residual soil were put back in its place. However, this was not the case for the numerous root fractures and small solution channels, particularly in the valley floor, which without sealing would result in piping beneath the impervious core.

The second factor of importance was the size of the mine rock for the first phase construction. A plot of the grain size distribution of the two samples described in correspondence dated July 25, 1962, is shown in Fig. 1. About 50 per cent of the material is finer than one inch and 15 per cent pass the number 10 sieve (2.00 mm). This means that the fill would not have a permeability great enough to permit storm water to pass through the rock section without overtopping. This factor is significant since it requires about two days to lower the reservoir level to 805 and if a second storm were to come within this lowering period breaching of the dam would occur. This required a modification in the design of the first phase.

The exposure of the firm rock surface for the first phase to approximately elevation 820, as mentioned, did not disclose solution channels with voids, but rather the channels were filled with colluvial material. It was recommended that removal of the residual soil from beneath the base of the dam, other than that already removed for the first phase, would not be necessary. Removal of residual soil and the

cleaning of the rock surface are expensive operations and were to be avoided if at all possible. In the redesign the residual soil was left in place except in the cutoff trenches required to control pore-water pressures and to provide toe drainage for seepage through the rock formations. The details of the excavations are shown on the new and revised drawings M19 to M24, inclusive, and in particular in plan each phase of construction is shown on Drawings M23 and M24.

The construction of the trench in the valley bottom to discharge storm water required rock excavation and backfill with rock of plus nine inch sizes. During the meetings held on May 31 and July 24, the writer was asked to reconsider the use of such a trench to discharge the storm water and to determine whether or not the trench could be eliminated. This necessitated a re-evaluation of the discharge characteristics of the dam for each phase of construction. Originally it was planned that the dam could be raised as desired, each lift depending on the availability of materials and the amount of tailings storage needed. In re-evaluating the problem of storm water discharge, it was decided that the simplest approach would be to use specific phases of construction and to provide a rock toe with each phase to control the velocities of the water emanating at the toe. The recommended construction for each phase of the dam necessary to maintain stability and to handle the discharge is shown on Drawings M19 to M24, inclusive.

This revised design because of the velocities of water emanating at the toe of the dam required throttling to minimize discharge and to

maximize storage in the reservoir during storm water runoff. It was found for other than first phase construction that a spillway 50 feet long satisfied the requirements and yet allowed the storm water stored in the reservoir to lower to the crest elevation sufficiently rapid as not to jeopardize the dam by overtopping with occurrence of a second storm during the period of lowering. The details of the spillway are shown on Drawings M20 and M24 and the design calculations are described under the chapter heading "Hydrology and Hydraulics".

*** The first four phases, as shown on Drawings M23 and M24, are designed to safely discharge the runoff for the critical 100 year design storm. The final phase was designed to handle the maximum probable design storm. However, sufficient freeboard above the spillway crest elevation was provided for the first phase as well as all subsequent phases so that the maximum probable design flood could be stored and discharged at a safe rate without overtopping the dam. Based on the computed flow characteristics of the dam for each phase of construction the phreatic surface within the dam was computed and the stability of both the upstream and downstream slopes determined. The computations for seepage and stability are summarized on Drawings M25 to M27, inclusive.

The report in its concluding chapters gives recommendations for the construction of the tailings dam with mine rock and cobber reject and also describes observations of seepage and slope stability that should be taken to check on the safety of the structure during the discharge of storm water and to control seepage and possible piping through the solution channels in the dolomites.

## HYDROLOGY AND HYDRAULICS

The rainfall records for Washington County, Missouri, presented in Table I were obtained from "Rainfall Frequency Atlas of the U. S., Technical Paper No. 40, Weather Bureau, U. S. Department of Commerce" for a return period of 100 years.

TABLE I

RAINFALL RECORDS FOR WASHINGTON COUNTY, MISSOURI

| Return Period | Rainfall in Inches For Durations of | | | | | | |
|---|---|---|---|---|---|---|---|
| Years | 30 min. | 1 hr. | 2 hrs. | 3 hrs. | 6 hrs. | 12 hrs. | 24 hrs. |
| 100 | 2.5 | 3.3 | 4.0 | 4.4 | 5.3 | 6.3 | 7.2 |

Based on the size and shape and slopes of the dam's 410 acre watershed, the time of concentration is approximately 0.6 hours. (Time of concentration is defined as the time required for a drop of water to travel from the farthest point of the watershed to the spillway outlet at the dam.)

First Phase. The first phase design section consists primarily of mine rock with an upstream impervious blanket. The impervious blanket extends from the bottom of the dam up to the invert elevation of the spillway. To permit discharge of storm runoff the mine rock from the spillway invert to the top of the dam is not blanketed by impervious soil. The impervious blanket is protected from wave scour and erosion by a blanket (riprap) of mine rock. Based on the grain size distribution of the mine rock as shown in Fig. 1, it is estimated that its permeability

is one centimeter per second. The impervious blanket which consists of locally available residual soil will have a permeability of approximately $10^{-6}$ or $10^{-7}$ centimeters per second and is considered impervious insofar as discharge of storm water through the dam is concerned. Therefore, it was assumed that during the first phase storm runoff is discharged through the exposed mine rock above the crest of the spillway at elevation 805. Assuming this constant spillway crest across the entire length of the dam, the elevation-discharge relationship was computed assuming laminar flow through the dam. A typical flow net is shown on Drawing M25. The elevation-discharge relationship is given in Fig. 2. As stated previously, when the reservoir level is below elevation 805, the spillway discharge is assumed to be zero.

The Snyder Method[1] of flood routing for synthetic hydrographs was used in the design. The assumed synthetic hydrographs consist of a constant rise in runoff (over a time period equal to the time of concentration of 0.6 hours) to a maximum runoff rate which is held constant (for the appropriate number of hours consistent with the duration and magnitude of the assumed storm as taken from Table I) and a constant fall in runoff (over a period of time equal to the time of concentration). Figure 3 shows the synthetic hydrograph derived from the 100 year - 2 hour duration design storm shown in Table I. This hydrograph neglecting losses by infiltration, retention, etc, is conservative.

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1 Snyder, F. F., "Synthetic Unit Graphs", Transactions, American Geophysical Union, Vol. 19, Part I, 1938, pp. 447-454.

Assuming the elevation-discharge relationship given on Fig. 2, and using the synthetic hydrograph, Fig. 3, and the elevation-storage relationship, Fig. 4, the 100 year - 2 hour storm was routed through the spillway. Figure 5 shows the relationship between time (from the beginning of the storm), spillway discharge and reservoir elevation. The maximum spillway discharge is 82 cubic feet per second, and the maximum reservoir rise is 5.8 feet to elevation 810.8.

To ascertain the maximum spillway discharge and reservoir rise, several other design storms as listed in Table I were routed through the spillway and the relationship between time, spillway discharge and reservoir elevation was determined for each case. The two hour storm was found to be critical.

Based on a method established by the Bureau of Reclamation[2] the maximum probable storm which could take place in the watershed was computed. The runoff hydrograph for this design storm is shown in Fig. 6. This hydrograph is based on the following assumptions.

(1) A 6 hour, 10 square mile probable maximum precipitation of 27 inches.

(2) Serious loss of life is not envisioned since the farmers living downstream will have evacuated in the event of such a catastrophic flood long before a failure would occur.

(3) A watershed consisting of thick vegetation of shrubs and clayey soils.

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2 "Design of Small Dams", U. S. Department of the Interior, Bureau of Reclamation, 1960.

(4) A moisture condition in the watershed of complete saturation at the onset of the design storm.

(5) A time of concentration of 0.6 hours.

(6) A watershed area of 410 acres.

Routing the storm hydrograph through the first phase results in the time, spillway discharge, reservoir elevation relationships shown in Fig. 7. The maximum spillway discharge is 143 cubic feet per second and the reservoir level rises from elevation 805 to elevation 817.9 - a depth of 12.9 feet. However, since the possibility of the maximum probable design storm occurring during the lifetime of the first through fourth phases of construction is extremely remote, these phases were designed and analyzed for stability assuming a 100 year return period and only the final phase was designed to handle the maximum probable design storm. As a safety precaution however, 15 feet of freeboard above the impervious blanket was left for each of the first four phases so that the maximum probable design storm could be stored and eventually discharged. The length of time of discharge from the start of the storm is about 30 hours for the critical 100 year flood. A height of freeboard of 15 feet is considered safe since the eventuality of a second storm occurring during the period of lowering of storm water to the spillway crest is remote.

Second Phase. The second through final phases will be constructed primarily of cobber reject rock. The cobber reject is a non-uniformly graded gravel varying in diameter from one-quarter to five-eighths inches. The coefficient of permeability of this size material is approximately 40 to 50 centimeters per second, much greater than the one centimeter per

second for mine rock. Since the hydraulic characteristics of the cobber reject are markedly different than those of the mine rock, the method of analysis for the second through final phases was changed from a simple laminar seepage flow to a combination weir-type and open channel-type flow. An investigation of the flow of water through rock fill has been performed by J. K. Wilkins[3]. He reports that the flow of water through rock fill in the region over the top of the impervious blanket is similar to a weir-type flow and the discharge q per foot length of spillway is given by

$$q = \sqrt{gh^3}\left(\frac{e}{1 + e}\right) \qquad (1)$$

where q is the spillway discharge in cubic feet per second per foot length of spillway,

g is the acceleration due to gravity - 32.2 feet per second squared,

h is the height of the water above the spillway invert in feet,

e is the void ratio of the cobber reject (ratio of volume of voids to volume of solid rock for one cubic foot of material in place in the dam).

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3 Wilkins, J. K., "Flow of Water Through Rockfill and Its Application to the Design of Dams", Second Australian-New Zealand Soil Mechanics Conference Proceedings, 1956, pp. 141-149.

The total discharge over the spillway Q is given by

$$Q = qL = L\sqrt{gh^3}\left(\frac{e}{1 + e}\right) \qquad (2)$$

where L is the length of spillway in feet.

In order to establish the most feasible length of spillway various design storms were routed over spillway lengths of 700 feet (the entire length of the dam at spillway elevation 825), 200 feet and 50 feet using a void ratio of 0.6 for the cobber reject. In these calculations the 100 year - 1 hour design storm was found to be critical. Table II summarizes the computations. The effect of shortening the length of spillway is readily apparent, i.e., the maximum spillway discharge is greatly reduced and the reservoir level is increased. In effect, as the spillway length is shortened more of the design storm is stored

TABLE II

SUMMARY OF MAXIMUM SPILLWAY DISCHARGE AND RESERVOIR RISE
FOR THE 100 YEAR - 1 HOUR DESIGN STORM
ROUTED THROUGH THE SECOND PHASE FOR VARIOUS SPILLWAY LENGTHS

| Length of Spillway Feet | Maximum Spillway Discharge cfs | Rise in Reservoir Above Elevation 825 Feet |
|---|---|---|
| 700 | 1280 | 0.9 |
| 200 | 830 | 1.6 |
| 50 | 375 | 2.4 |

in the reservoir. This is an important concept when constructing dams from locally available materials having limited grain size distributions

since the maximum spillway discharge must be throttled to the extent that not only a safe but also an economical design is achieved. If the rock fill were more pervious large discharges through the dam would occur with a correspondingly smaller rise in reservoir level. Without a better understanding of the disturbance of tailings when a storm passes through the reservoir and the increase in turbidity, it is difficult to determine the rise in reservoir level that should be used to minimize turbidity. From a hydraulic point of view it is desirable to lower the reservoir level as quickly as possible in anticipation of a second storm. Turbidity is least for that flow which permits the longest detention time of a storm in its passage through the reservoir. The selection of the length of spillway was made considering this and the requirement that the time for lowering of the reservoir to spillway crest from the start of a storm should not exceed 30 hours for the 100 year - 1 hour storm.

The effect of throttling the spillway discharge may be better seen by examining the manner in which the water travels through the dam after having passed over the spillway. Once over the spillway, the water tends to cascade down through the cobber reject and pile-up on the valley floor at the base of the dam. From there the flow through the dam has open channel hydraulic characteristics, with the exception that in this case the channel is filled with cobber reject. The velocity of this flow as determined experimentally by Wilkins, is given by the equation

$$V = 3.3\ m^{0.5}\ i^{0.54} \qquad (3)$$

where V is the velocity of flow in feet per second through the voids of the cobber reject,

m is the hydraulic mean radius in inches,

i is the hydraulic gradient in feet per foot of path length.

The hydraulic mean radius m is given by

$$m = \frac{eD}{6} \qquad (4)$$

where e is the void ratio,

D is the average diameter.

Using e = 0.6 and D = 0.437 inches for cobber reject Eq. (3) becomes

$$V = 0.694\ i^{0.54} \qquad (5)$$

By applying continuity Q=VA where A is the cross sectional area of flow and the fact that the hydraulic gradient i equals the rate of change of the depth of water H above the valley floor with respect to distance X from the downstream toe of the dam the equation for the phreatic surface is

$$H = 0.989\ Q^{0.409}\ X^{0.221} \qquad (6)$$

where H is the height in feet of the water above the tailwater within the dam,

Q is the maximum spillway discharge in cubic feet per second,

X is the distance in feet from the downstream toe to a given point within the dam for which H is being computed.

Figure 8 shows schematically the interrelationship of H, X and i. Equation (6) also reflects the manner in which the cross-sectional area of the valley changes with height above the valley floor. Figure 9 shows the computed phreatic surfaces for the maximum discharges obtained for a spillway having a length of 700, 200 and 50 feet. Computations show that as the spillway discharge increases the height of water within the embankment increases and correspondingly, the stability of the downstream slope decreases. It is therefore advantageous to minimize spillway discharge by throttling the flow with a narrow spillway. Consequently, a spillway width of 50 feet was adopted. As shown in Table II, a 50 foot spillway results in a maximum discharge of 375 cfs and a rise of 2.4 feet in the reservoir level.

The maximum probable design storm was also routed through the second phase. This storm has a maximum spillway discharge of 1210 cfs and causes a rise in the reservoir of 5.2 feet. The top of the second phase was therefore set at elevation 840 which provides a total depth of spillway of 15 feet. This depth of spillway was provided for the following reason. The computed hydraulic characteristics of the cobber reject may differ from the in-place characteristics and the extra freeboard will provide a sufficient safety factor against the possibility of overtopping the dam.

Due to the small grain sizes of the cobbjer reject, storm runoff discharged through the dam will have a tendency to scour and drag the cobber reject downstream. To minimize the damaging effects of scour, the downstream toe of the dam has to be protected by a rock

toe as shown on Drawings M19 and M24. This toe should consist of rock having a minimum size of 6 inches in diameter. It has been possible to minimize the extent of this toe by throttling the spillway discharge with a 50 foot spillway.

Third and Fourth Phases. The hydraulic characteristics of these two phases are intermediate between the second and final phase and therefore, these computations were not carried out.

Final Phase. The final phase was designed to safely discharge the maximum probable design storm. The crest of the final phase spillway was set at elevation 890. The elevation-discharge relationship for various lengths of spillway was computed from Eq. (2). Using the runoff hydrograph shown in Fig. 6 for the maximum probable storm, the reservoir elevation and spillway discharge relation was computed for spillway lengths of 1130 feet (the entire length of the dam) and 50 feet. Table III summarizes the calculations. The effect of shortening the spillway length is apparent. Shortening the spillway length to 50 feet

TABLE III

SUMMARY OF MAXIMUM SPILLWAY DISCHARGE AND RESERVOIR RISE
FOR THE MAXIMUM PROBABLE DESIGN STORM
ROUTED THROUGH THE FINAL PHASE FOR VARIOUS SPILLWAY LENGTHS

| Length of Spillway Feet | Maximum Spillway Discharge cfs | Rise in Reservoir Above Elevation 890 Feet |
|---|---|---|
| 1130 | 1630 | 0.8 |
| 50 | 250 | 1.8 |

decreases the maximum spillway discharge from 1630 cfs to 250 cfs. A discharge of 250 cfs keeps the phreatic surface well within the dam increasing the stability of the downstream slope and requiring a small rock toe. The spillway length was therefore set at 50 feet for the final phase, as was the case for the previous three phases. A freeboard of ten feet is provided with the breast elevation of the dam at 900.

In the light of recent developments, the Pea Ridge tailings dam has been redesigned to maintain a safe, economical structure. The use of a 50 foot wide spillway for other than first phase construction has the following advantages:

(1) Eliminates the need for excavating a trench in rock along the valley floor.

(2) Eliminates the need of excavating the residual soil to rock beneath the entire area to be occupied by the dam.

(3) Results in an improved hydraulic design since the spillway discharge can be throttled to flows consistent with the hydraulic properties of the cobber reject and mine rock which is composed mostly of small rock sizes.

(4) Increases the stability of the downstream slope, because of the throttling of the storm water.

(5) Results in a better hydraulic design by controlling the region of spillage within the dam. The spillway notch is placed at a location for each phase of construction which permits the flow to enter the downstream valley with a minimum of turbulence.

## STABILITY

First Phase. The stability computations for the first phase construction are summarized on Drawing M25. The cross-section shown was taken at Station 6 + 00. The flow through the mine rock is based on the assumption that the spillway crest is at elevation 805 and that the reservoir is at elevation 818. This is a conservative assumption since the maximum reservoir elevation for the routed 100 year - 2 hour design storm is elevation 810.8. However, this computed reservoir elevation is based on an assumed coefficient of permeability for the mine rock of one centimeter per second and if the in-place permeability of the mine rock is much less the rise in the reservoir would be much greater than elevation 810.8. Thus the conservative reservoir elevation 818 is warranted.

Table IV summarizes the minimum factors of safety for the stability of the first phase. These values are based on an assumed

TABLE IV

MINIMUM FACTORS OF SAFETY
FOR STABILITY OF THE FIRST PHASE

| Slope | Safety Factor | Remarks |
|---|---|---|
| Upstream | 3.39 | Assuming that the reservoir is at elevation 818 (See Drawing M25) |
| Downstream | 1.32 | Assuming that the reservoir is at elevation 818 (See Drawing M25) |
| Upstream | 3.26 | Assuming that the reservoir is empty |
| Downstream | 2.41 | Assuming that the reservoir is at elevation 805.0. |

angle of internal friction, ∅, for mine rock of 42 degrees. With the reservoir level at elevation 818 the minimum factors of safety are 3.39 and 1.32 for the upstream and downstream slopes, respectively. The low factor of safety of 1.32 for the downstream slope is acceptable since it was obtained under the extreme condition of a high water level. This value increases from 1.32 to 2.41 when the reservoir is at elevation 805, that is there is no flow over the spillway. Since it is highly probable that during the lifetime of the first phase, the reservoir will rise no higher than elevation 810.8, the factor of safety will be somewhere between the two values, 1.32 and 2.41.

The factor of safety for the upstream slope decreases from 3.39 to 3.26 when the reservoir is empty.

Second Phase. Drawing M26 summarizes the stability calculations for the second phase. The cross-section shown was taken at Station 5 + 75, the centerline of the spillway. The crest of the spillway is at elevation 825. As shown in Table II, the maximum spillway discharge is 375 cfs for a 50 foot long spillway. The corresponding slope of the phreatic surface, as computed by Eq. (6), for this flow is shown on Drawing M26. Since the hydraulic properties of the cobber reject are based on experimentally determined data the stability computations were based on a spillway depth of 2.4 feet as the theoretical weir discharge as computed from Eq. (2) was considered reliable. Table V lists the minimum factors of safety for the stability of the second phase. These safety factors are based on an angle of internal friction, ∅, of 42 and 35 degrees for the mine rock and cobber reject, respectively. During flood

TABLE V

MINIMUM FACTORS OF SAFETY
FOR STABILITY OF SECOND PHASE

| Slope | Safety Factors | Remarks |
|---|---|---|
| Upstream | 8.06 | Assuming that the reservoir is at elevation 827.4 (See Drawing M26) |
| Downstream | 1.72 | Assuming that the reservoir is at elevation 827.4 (See Drawing M26) |
| Downstream | 2.30 | Assuming that the reservoir is at elevation 825.0 |

conditions the minimum factors of safety are 8.06 and 1.72 for the upstream and downstream slopes, respectively. When the reservoir is at elevation 825 (spillway crest), the factor of safety increases from 1.72 to 2.30.

Final Phase. For this phase and a cross-section through Station 5 + 00, the centerline of the spillway, stability calculations are shown on Drawing M27 and the factors of safety are brought together in Table VI. The crest of the spillway is at elevation 890. The maximum rise in the reservoir for the maximum probable design storm is 1.8 feet and the corresponding discharge is 250 cfs. These values were used to determine the phreatic surface as shown in Drawing M27.

During flood conditions the minimum factors of safety are 7.75 and 1.70, for the upstream and downstream slopes, respectively. When the reservoir is at spillway crest (elevation 890) the safety factor for the downstream slope increases from 1.70 to 1.73.

TABLE VI

MINIMUM FACTORS OF SAFETY
FOR STABILITY OF FINAL PHASE

| Slope | Safety Factor | Remarks |
|---|---|---|
| Upstream | 7.75 | Assuming that the reservoir is at elevation 891.8 (See Drawing M27) |
| Downstream | 1.70 | Assuming that the reservoir is at elevation 891.8 (See Drawing M27) |
| Downstream | 1.73 | Assuming that the reservoir is at elevation 890.0 |

The calculations show that both the upstream and downstream slopes of the dam are stable for all phases of construction. The safety factors listed in Tables IV to VI for the upstream slope will be increased once the tailings begin to settle against the upstream face of the dam. The safety factors for the downstream slope are related to the quantity of discharge passing over the spillway. And the decrease in factor of safety from that value computed for no flow over the spillway is greatest for the first and second phases of construction when the 100 year storms are passing through the dam. For similar flood storms the reduction in factor of safety is negligible for final phase construction. For the second through final phases a heavy rock toe is required along the downstream toe of the dam to prevent the scouring of the cobber reject during storm water flows.

RECOMMENDATIONS FOR CONSTRUCTION

1. The proposed tailings dam should be constructed in accordance with new and revised Drawings M19 to M24 inclusive and in accordance with items of specifications that remain pertinent to the revised design. The specifications were submitted in November, 1961.
2. The large solution channels and crevices that are clay filled should be excavated and refilled with compacted residual soil as shown on Drawing M23. This sealing should only be made beneath that portion of the impervious core formed by the projection of the parallel slopes of the impervious core onto the rock surface.
3. The small solution channels, root fractures and other cracks that cannot be effectively sealed with residual soil should be covered with a layer of concrete as shown on Drawing M23. This covering is only required beneath the projection of the slope surfaces of the impervious core onto the rock surface.
4. The ledges uncovered beneath the impervious core should be excavated to form a notch and to provide a long flow line in a manner similar to that shown by Detail A on Drawing M23.
5. The residual soil and weathered rock to the firm rock surface should be excavated from beneath the dam as shown on Drawings M23 and M24. Since most of the residual soil has been removed for first phase construction, it is not necessary to remove additional material from the toe should the downstream slope of the first phase extend beyond the excavation of residual soil made to date. The timing of the excavation

for the cut-off trenches should be in accordance with that shown on Drawing M24.

6. The pipes required to measure seepage through the large crevice on the south abutment and through the root fracture in the valley bottom should be installed in a manner somewhat similar to that shown on Drawing M23.

7. The mine rock for first phase construction should be placed in lifts not exceeding 12 inches and should be compacted with the crawler equipment used for spreading of the dumped material. There is no need to separate or select large mine rock for the pervious core through the central cross section of the dam. The rock should be placed as required to facilitate raising of the dam and as it is received from the mine development.

8. The transition zone between the impervious core and the mine rock for the first phase construction should be a mixture of fine mine rock and coarse residual soil. The material should be tested for grain size distribution and the test results should be forwarded to us to determine whether or not this transition material has the proper filtering properties for the water permeating through the relatively impervious core. A similar statement applies to the material for the transition zone required between the impervious core and cobber reject for second to fifth phases of construction of the dam.

9. The impervious core should be residual soil taken from the excavations for the base of the dam and from adjacent borrow areas. The material should have a classification of clayey silt and should contain a minimum

of particles of gravel and rock size. It is important, in the construction of the impervious core, since a minimum thickness is used, that rock and gravel do not collect in clusters forming in effect drains through the impervious core. Rock is permissible provided that each particle of rock is embedded in a matrix of clayey silt. In construction of the impervious core the rock and gravel sizes should be raked towards the upstream face of the impervious core. The materials for the impervious core should be compacted in accordance with Detailed Specifications, Item 9, of specifications submitted November, 1962. If the materials for the impervious core are different than those described in the "Report of Soil Investigation for Meramec Mining Company, Pea Ridge" by John B. Heagler, Jr., on July 13, 1960, the soils should be tested for their grain size distribution and results should be forwarded to us for analysis.

10. The cobber reject for second to fifth phases of the construction should be placed in lifts not exceeding 12 inches and should be compacted with crawler equipment used to spread the cobber that is dumped from trucks.

11. The upstream face of the impervious core should be covered with a layer of riprap composed of mine rock, cobber reject or quarried dolomite, or any combination of these materials.

12. The rock for the toe drains as shown on Drawing M24 should be either large mine development and/or quarried rock having a diameter greater than six inches. This material should be placed in lifts equal to the size of the largest rock and should be compacted with heavy crawler

equipment into a dense state. Crushing of the rock and the formation of thin relatively impervious layers of broken rock with the placing of each lift should be avoided. It is essential that the rock toe have large unobstructed voids to permit a practically free movement of water through the toe.

In the operation of the dam it is recommended for at least the first, second and possibly the third phases that tailings be dumped against the upstream slope of the dam and on the north and south abutments so that sealing of the reservoir can proceed from the face of the dam upstream in the basin. Thereafter, because of the need to maintain a 30 to 50 foot drop in the pipe line from the clarifier and thickener to the point of outflow the tailings can be discharged into the upper reaches of the reservoir. The beneficial sealing effect of the tailings should be gained immediately in the early phases of the construction of the tailings dam. Even though precautions have been taken to seal solution channels there is always the danger in dolomite formations that piping with dire consequences may occur. Should the tailings not provide the sealing required and should seepage through the rock formations reach a state in which fines are being transported by the escaping water, grouting of the rock beneath the impervious core would be required. There should be no concern about the magnitude of the seepage even though it is heavy, provided that fines are not being transported by the ground water. Experience with other tailings dams founded on pervious rock formations indicates that the tailings do seal the reservoir and the economic advantage of this factor has been taken into account in the proposed method of construction of the tailings dam.

## OBSERVATIONS

As a check on the performance of the tailings dam and to gather data that may be advantageous in reducing the cost of construction of phases other than first phase construction, and to maintain a control on seepage, the following observations should be made and records maintained.

(1) The as-built drawings should show the location of solution channels, crevices, fractures and other openings through which water may escape beneath the impervious core. These features, along with the location of ledges, should be shown in both plan and elevation. Should grouting measures be required to maintain the integrity of the dam, the accurate known location of the solution channels would greatly reduce the cost of corrective measures.

(2) A gage should be set at each spillway to determine the amount of water flowing over the spillway and through the dam during and following periods of sustained precipitation and flood. Gage readings should be taken at least weekly and during and following periods of sustained precipitation and floods.

(3) Weirs should be placed at the downstream toe to determine the amount of water escaping through the rock formations. Flow measurements should also be made of the water escaping through the solution channel on the south abutment and through the root fracture in the valley bottom which were uncovered during the first phase construction. The metal pipes used to conduct

the seepage to the toe of the dam should be extended to the toe of each phase of construction. The extension of the pipes should only be discontinued if it has been conclusively determined that seepage through the solution channel and root fracture is negligible and that the tailings have sealed the reservoir. Readings of flow over weirs should be taken at least weekly and during and following periods of sustained precipitation and floods.

(4) A rain gage station should be installed and records of total weekly precipitation should be maintained.

(5) Concrete plugs having a plan dimension at least 6 inches by 6 inches and a length of 18 inches should be embedded in the downstream slope of the mine rock for first phase construction and in the cobber reject for all other phases of construction. These plugs should be flush with the ground surface and should be located on three different sections approximately 100 feet apart within the central portion of the downstream face. Five observation plugs should be set at approximately equal increments of height in each cross section. Readings of changes in elevation and rotation of each plug should be made after the passage of each major storm through the dam. The plugs are necessary to determine the movement of the downstream slope occurring with the discharge of floods through the dam.

(6) During filling of the reservoir following completion of first phase construction, daily readings if necessary, of the rise

in water level and seepage over the weirs should be taken. In any event readings should be taken at least weekly during this period of filling.

(7) The residual soil placed in the impervious core should be tested for compaction and field densities and water content determinations should be conducted on at least each 500 cubic yards of material that is placed and more often if the residual soil placed in the impervious core varies in texture and if the method of compaction appears to be unsatisfactory.

(8) During each phase of construction the materials for the impervious core and transition zone should be sampled and tested for grain size distribution. The frequency of testing should be governed by the changes in texture of material used.

The above data should be forwarded to us for review and analysis and in particular for plotting of the flow data to determine whether or not ground water conditions are developing which may lead to distress. Should the ground water flow be excessive and the sealing of the reservoir by tailings be ineffective, the flow observations suggested above are essential for a proper evaluation of corrective measures in the form of grouting or relief weirs to control the flow without extraordinary expense.

Respectfully submitted,
E. D'Appolonia Associates

E D'Appolonia

E. D'Appolonia

Project No. 61-109
October 8, 1962

E. D'APPOLONIA ASSOCIATES

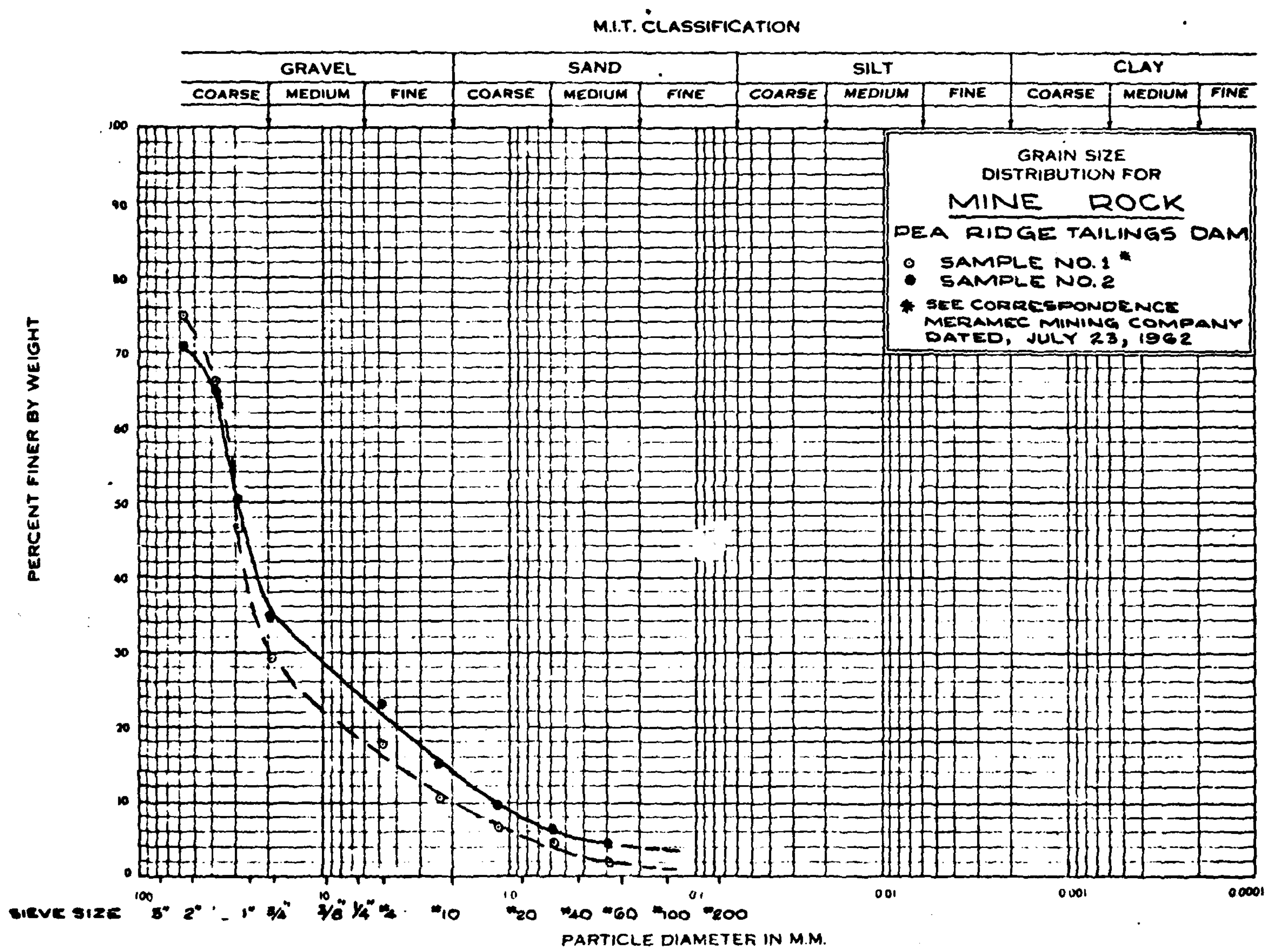



FIGURE 1

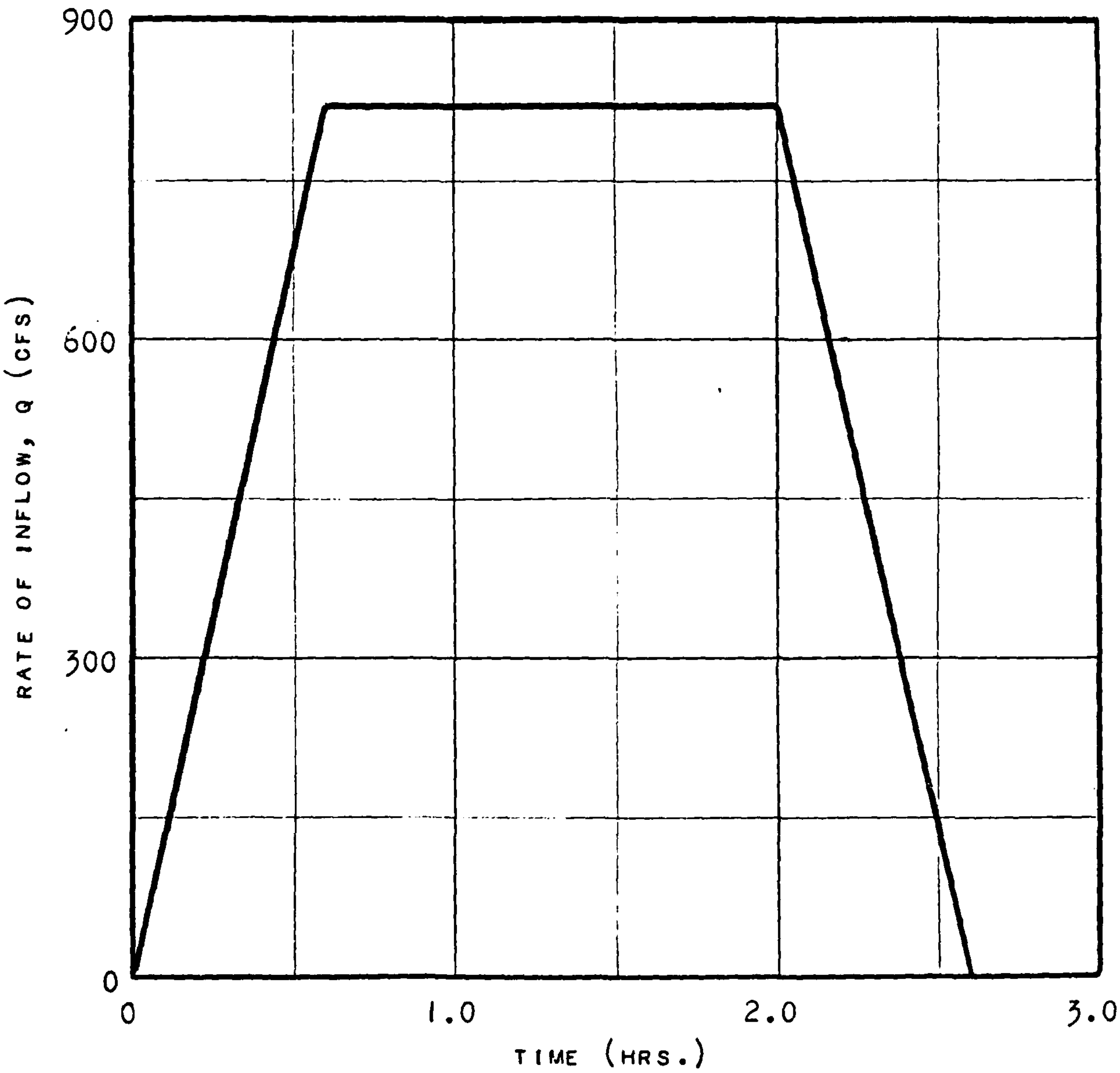



FIG. 3 SYNTHETIC HYDROGRAPH FOR A 100-YEAR - 2-HOUR DESIGN STORM

E. D'APPOLONIA ASSOCIATES

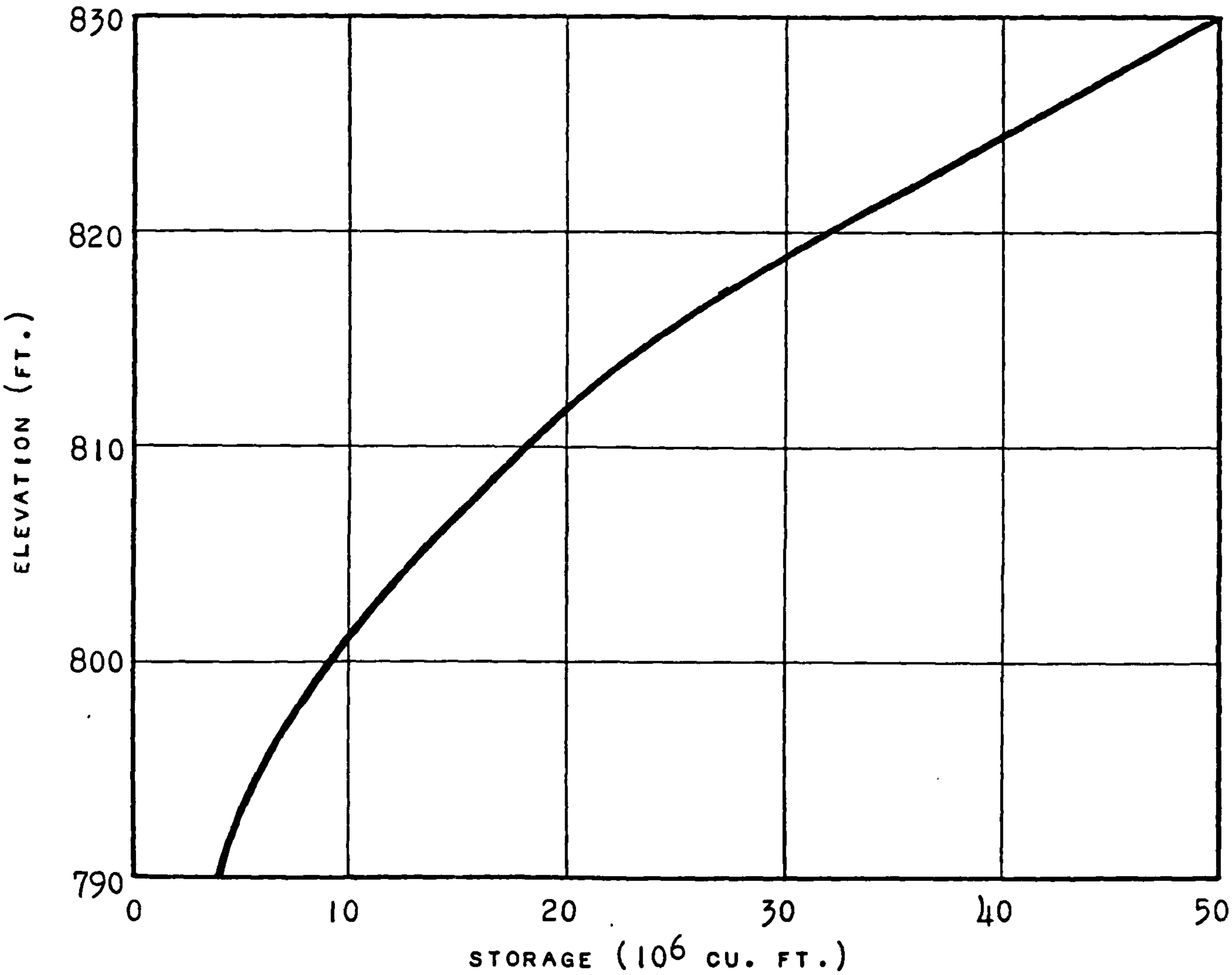



FIG. 4 ELEVATION-STORAGE RELATIONSHIP FOR RESERVOIR

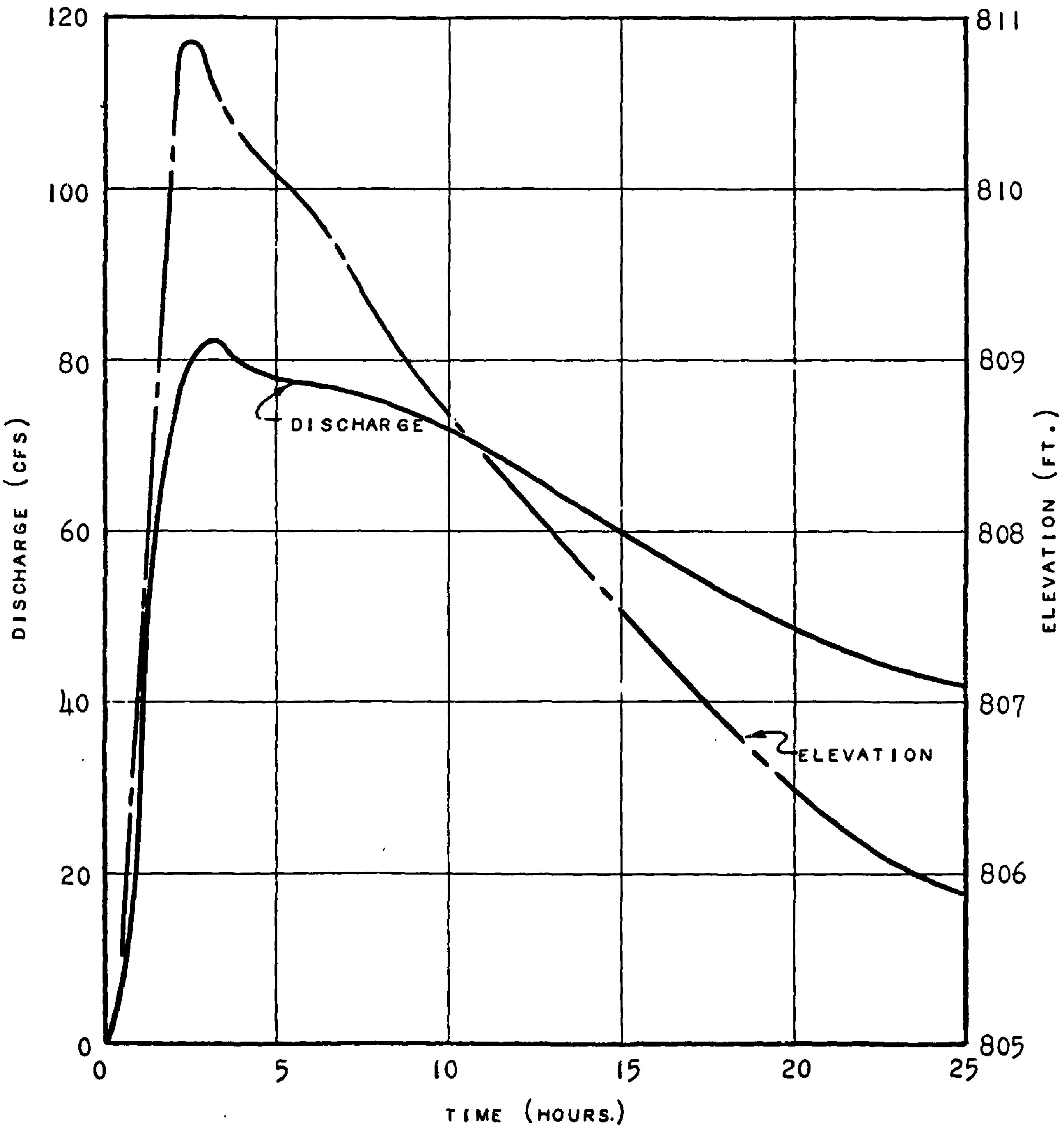



FIG. 5 RELATIONSHIP BETWEEN TIME, SPILLWAY DISCHARGE AND RESERVOIR ELEVATION FOR THE FIRST PHASE USING THE 100-YEAR - 2-HOUR DESIGN STORM

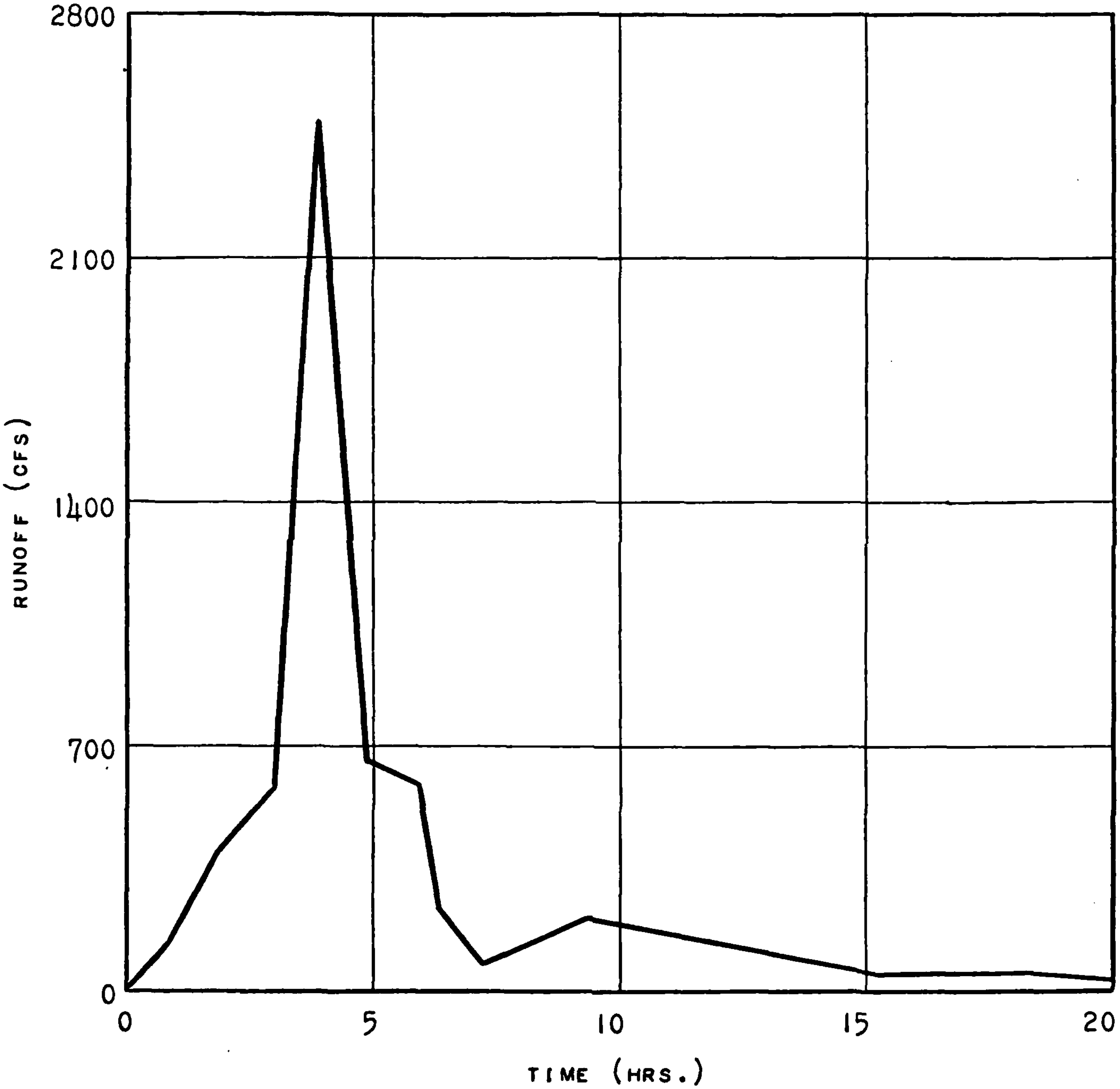



FIG. 6 RUNOFF HYDROGRAPH FOR MAXIMUM PROBABLE STORM

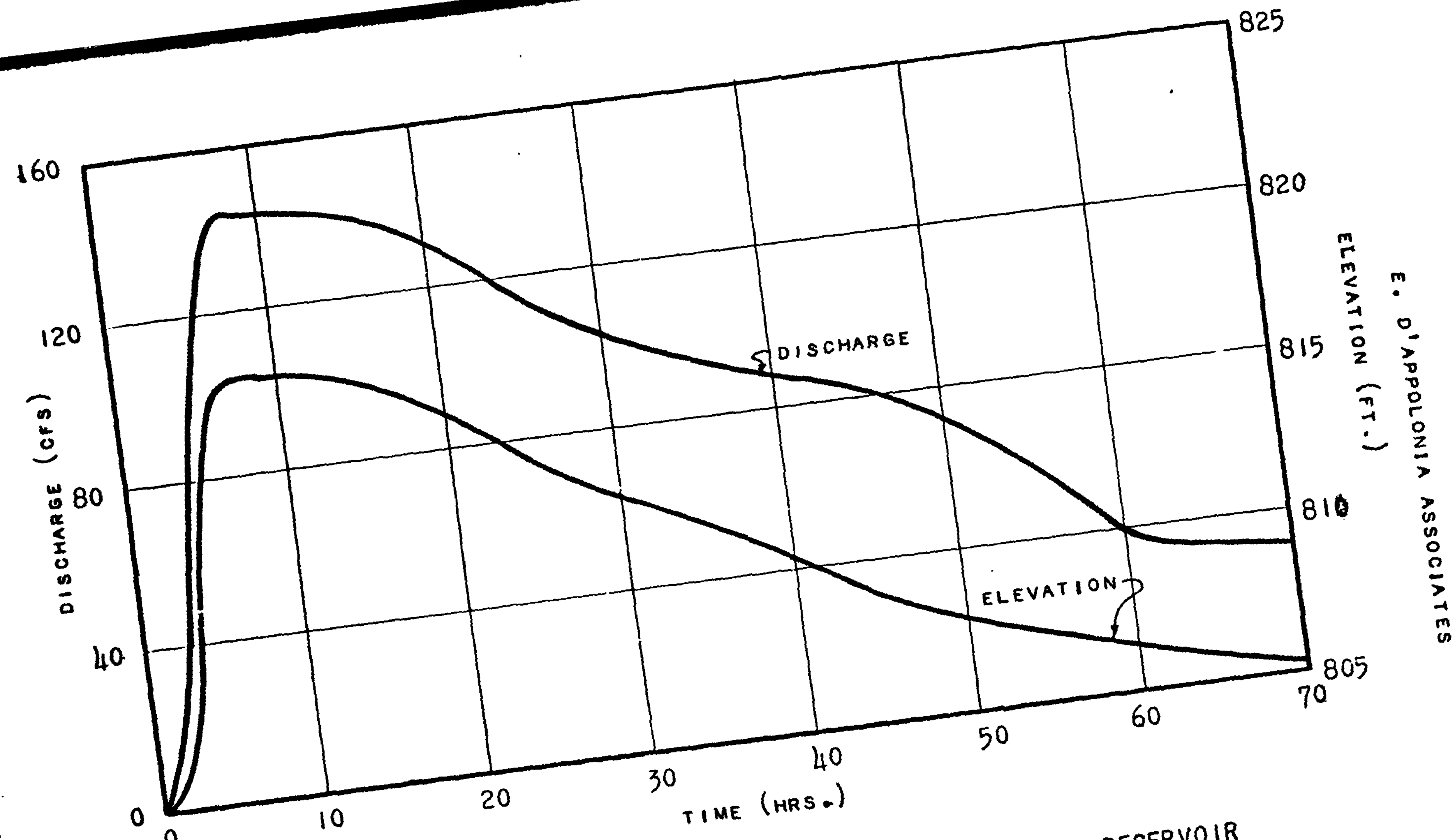



FIG. 7 RELATIONSHIP BETWEEN TIME, SPILLWAY DISCHARGE AND RESERVOIR ELEVATION FOR THE FIRST PHASE USING THE MAXIMUM PROBABLE DESIGN STORM

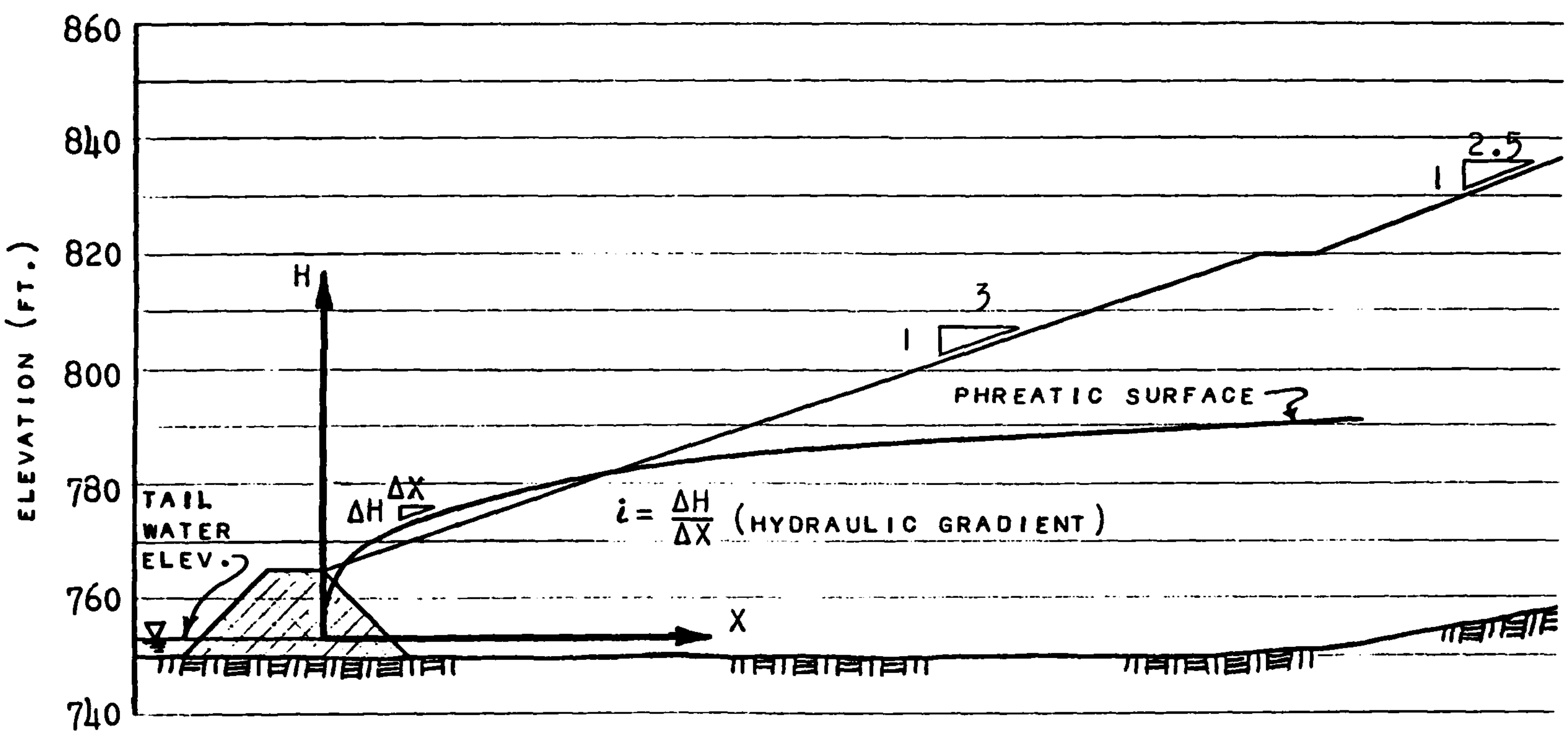
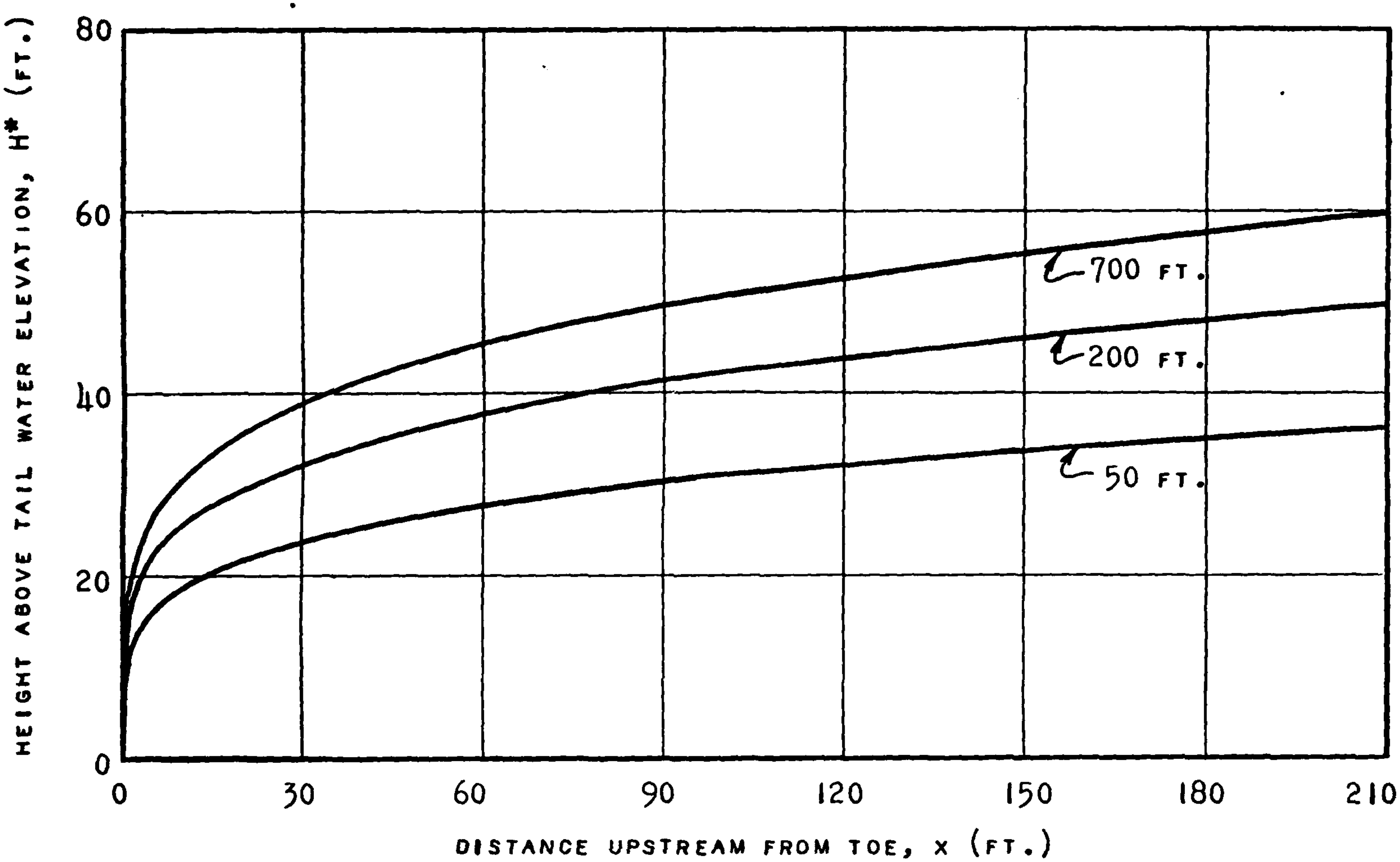
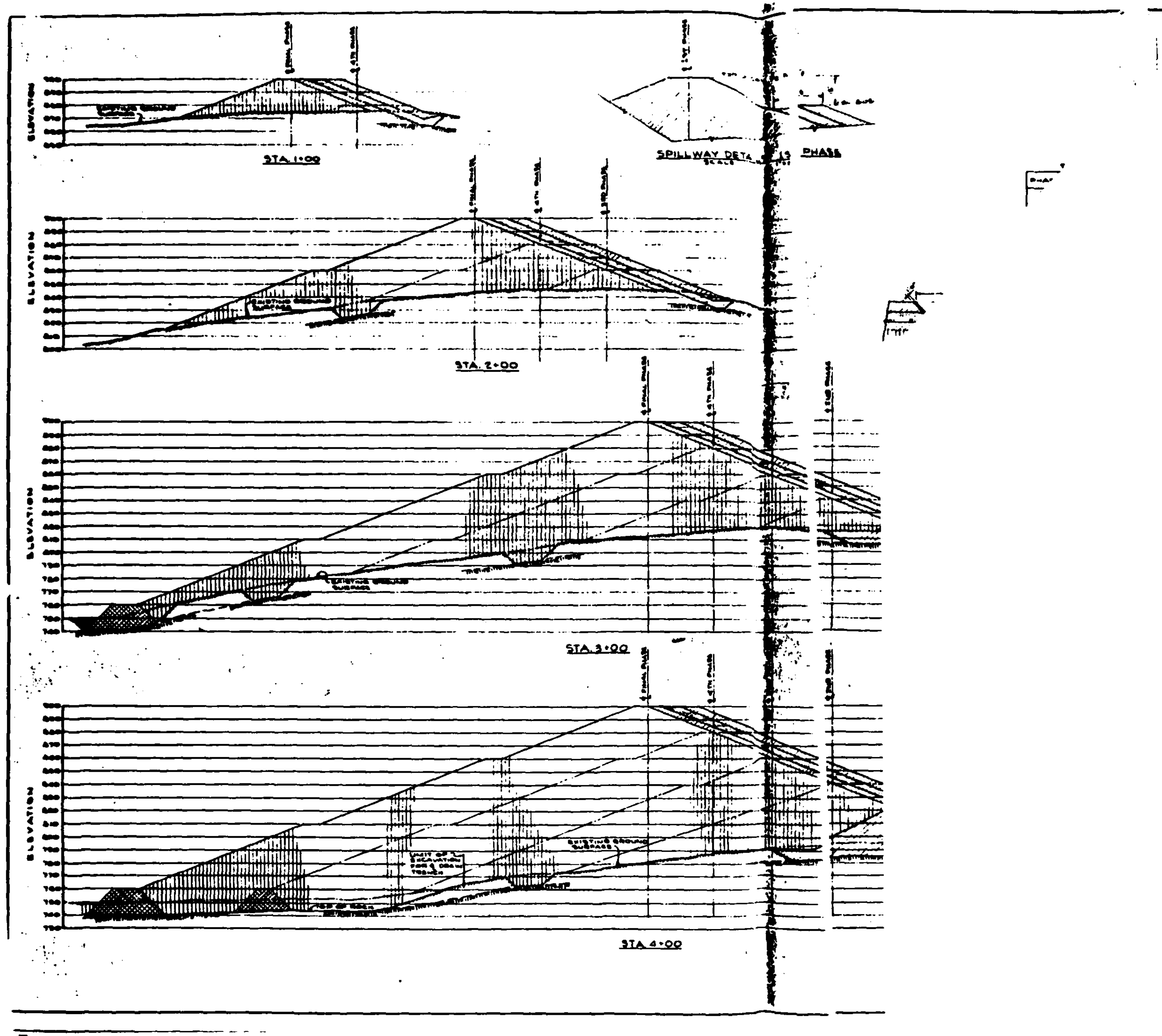


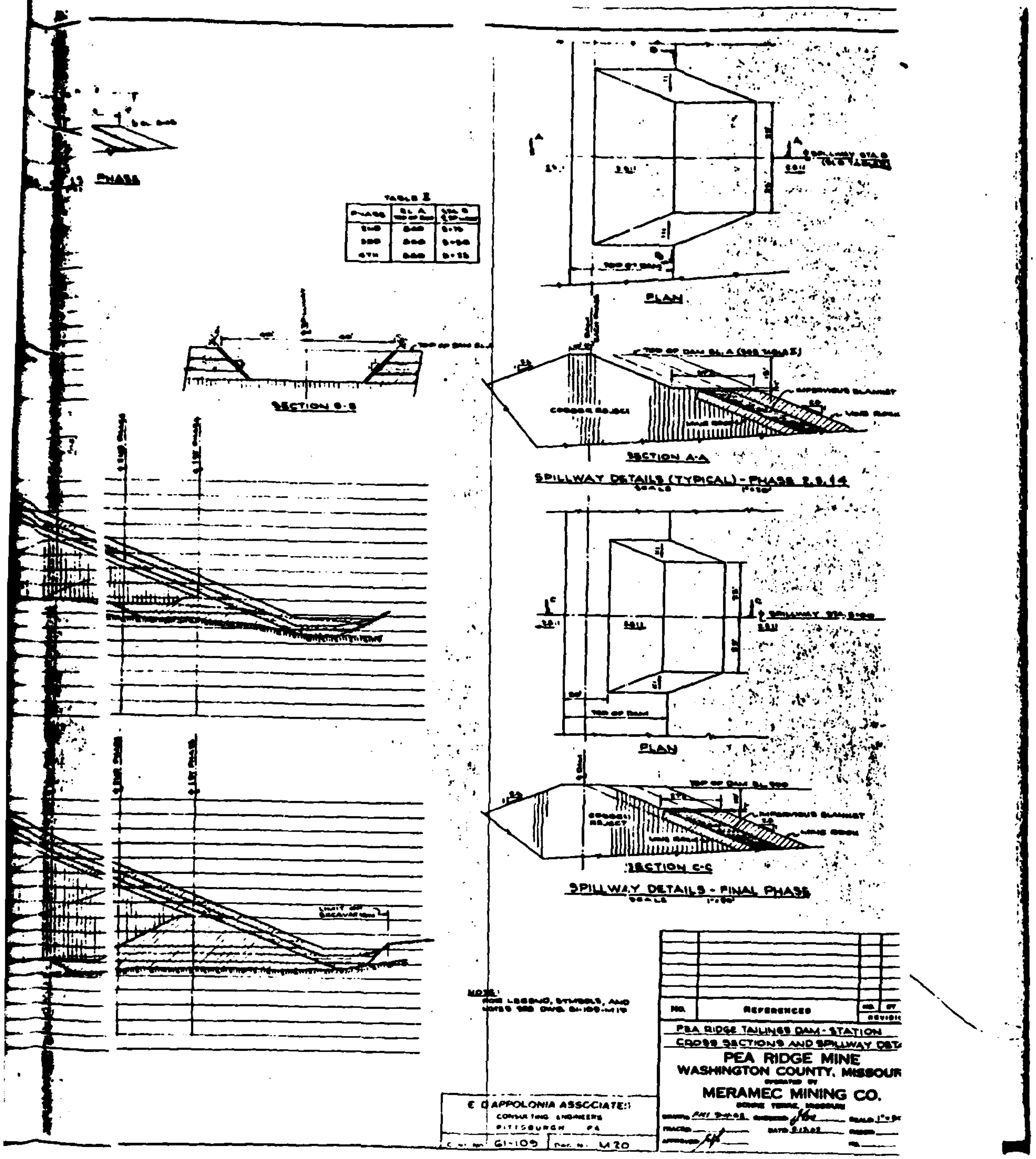

FIG. 8 SCHEMATIC DIAGRAM OF PHREATIC SURFACE

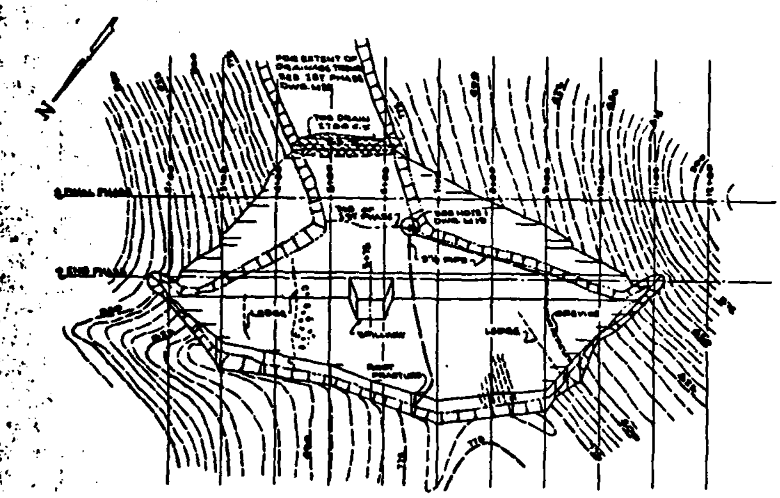



*HEIGHT MEASURED FROM TAIL WATER ELEVATION

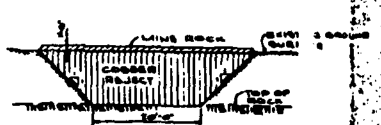
FIG. 9 PHREATIC SURFACES FOR 700 FOOT, 200 FOOT AND 50 FOOT SPILLWAYS FOR THE SECOND PHASE


ELEVATION
STA. 1+00
STA. 2+00
STA. 3+00
STA. 4+00
EXISTING GROUND SURFACE
SPILLWAY DETAIL
PHASE
TOP OF ROCK

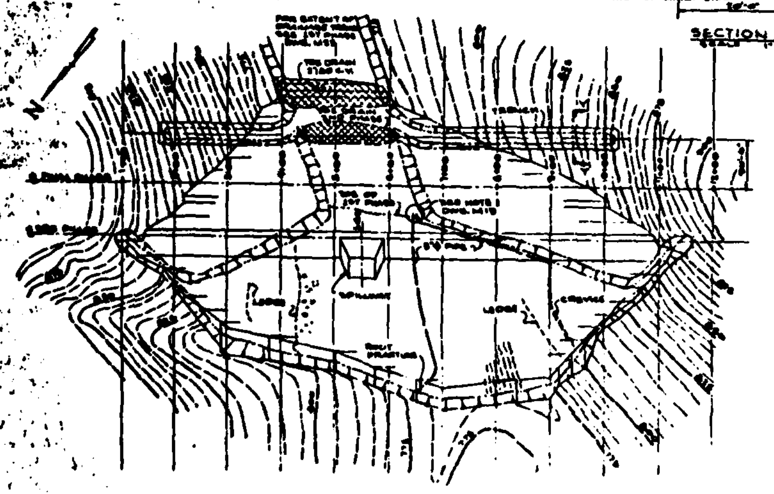

PHASE
SECTION B-B
PLAN
SECTION A-A
SPILLWAY DETAILS (TYPICAL) - PHASE 2,3, & 4
PLAN
SECTION C-C
SPILLWAY DETAILS - FINAL PHASE
NOTE:
FOR LEGEND, SYMBOLS, AND NOTES SEE DWG. 61-109-M19
E. D'APPOLONIA ASSOCIATES
CONSULTING ENGINEERS
PITTSBURGH PA
61-109
M20
NO.
REFERENCES
PEA RIDGE TAILINGS DAM - STATION
CROSS SECTIONS AND SPILLWAY DETA
PEA RIDGE MINE
WASHINGTON COUNTY, MISSOUR
MERAMEC MINING CO.



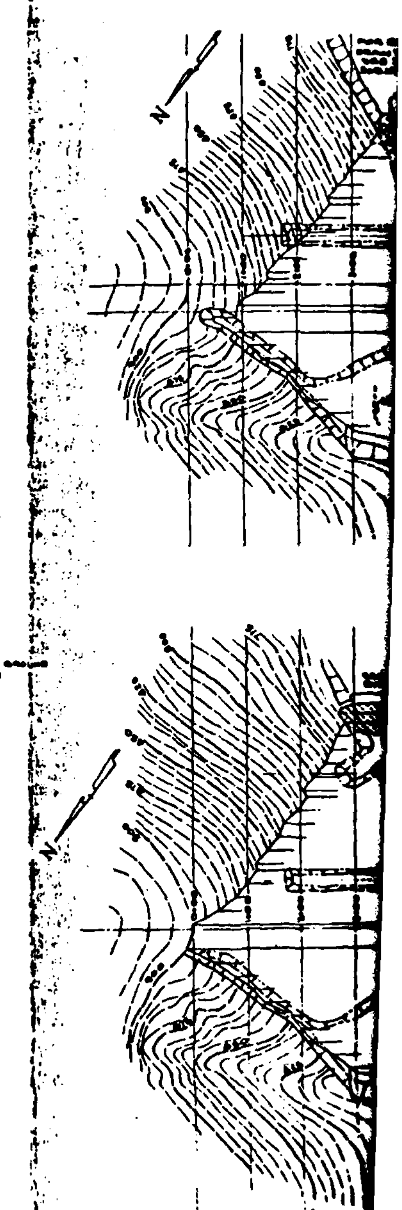
PLAN - 2ND PHASE




SECTION Y-Y



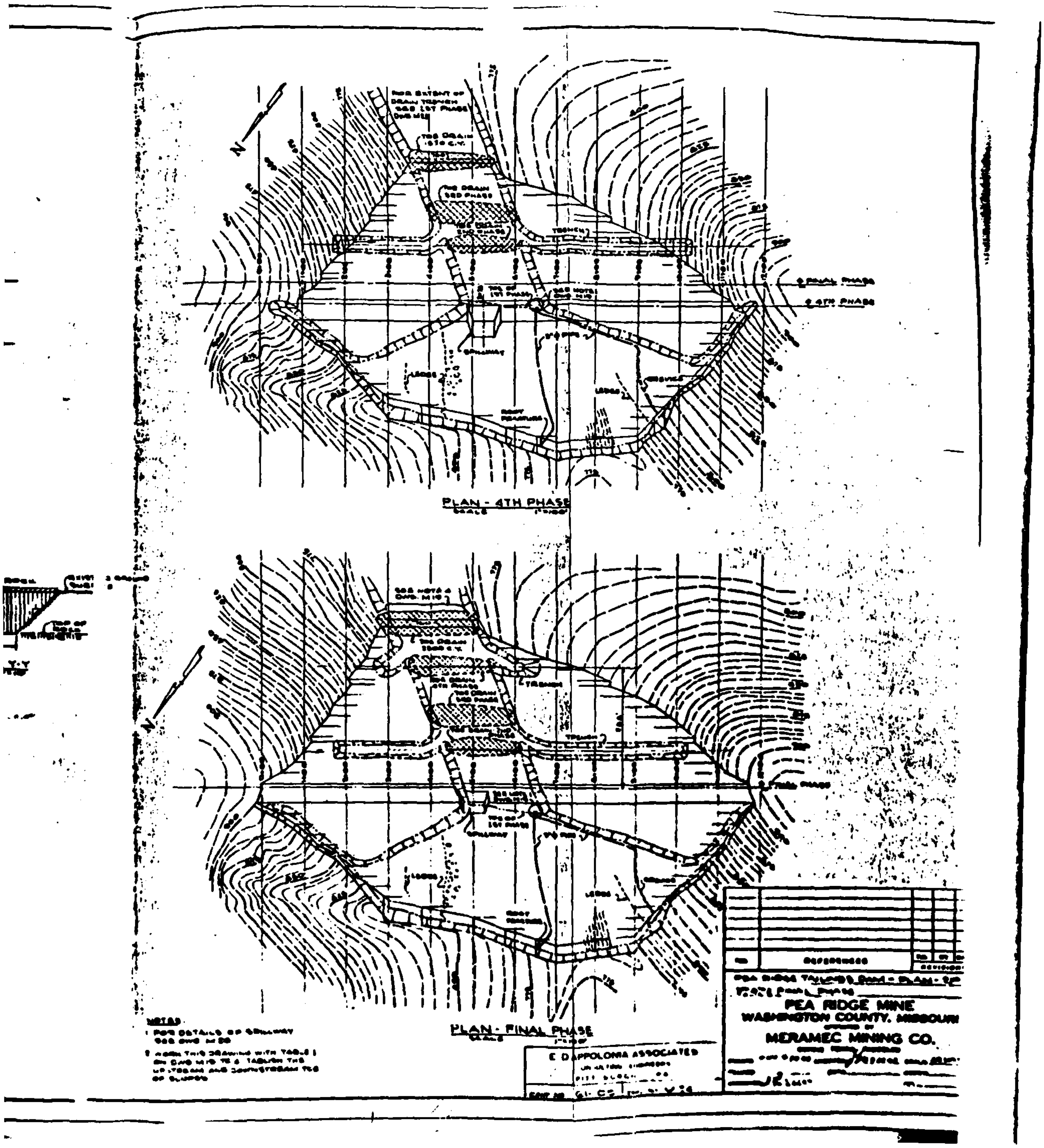
PLAN - 3RD PHASE

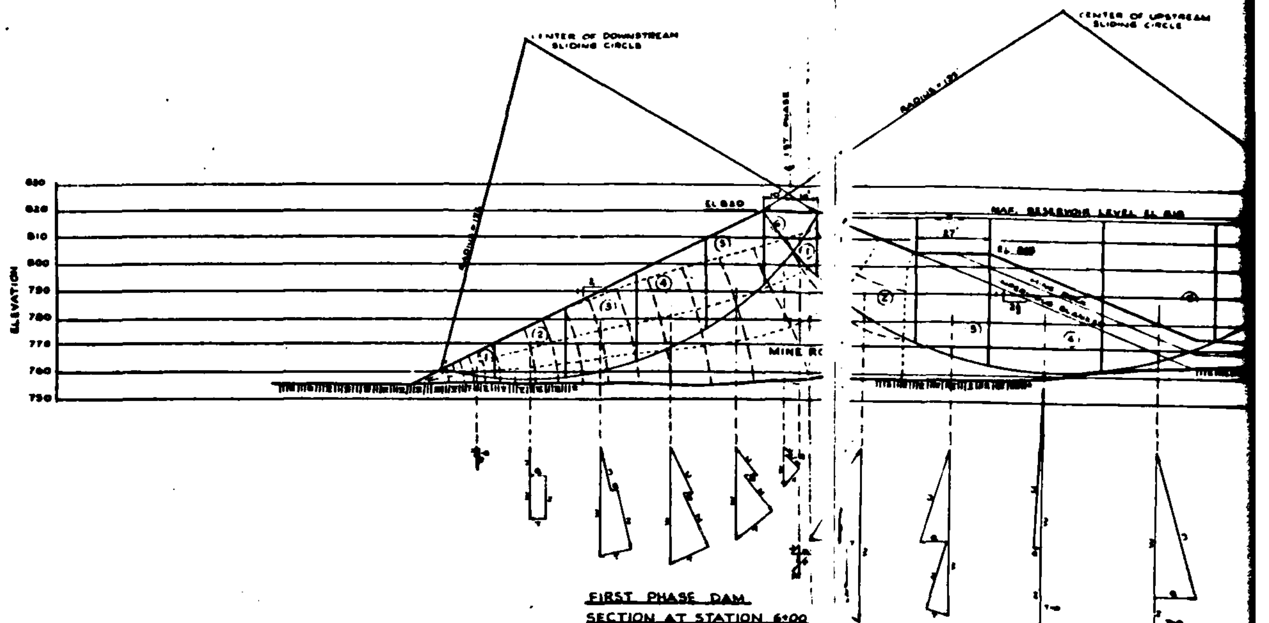


NOTES.

1 FOR DETAILS OF SPILLWAY SEE DWG M 20

2 [illegible] THIS DRAWING WITH TABLE 1 ON DWG M 19 TO [illegible] THE UPSTREAM AND DOWNSTREAM TOE OF SLOPES


PLAN - 4TH PHASE
SPILLWAY
TRENCH
PLAN - FINAL PHASE
REFERENCES
PEA RIDGE MINE
WASHINGTON COUNTY, MISSOURI
MERAMEC MINING CO.
E. D'APPOLONIA ASSOCIATES




FIRST PHASE DAM
SECTION AT STATION 6+00
Scale: 1" = 20 FT; 1" = 50 kips

DOWNSTREAM SLOPE STABILITY ANALYSIS

| SLICE NO | WEIGHTS | | | | | LATERAL HYDROSTATIC FORCE | | | | HYDROSTATIC UPLIFT | | | FRICTIONAL RESISTANCE | | | COHESION RESISTANCE | | TANGENTIAL WEIGHT COMPONENTS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DENSITY 0.11 K.C.F. | | DENSITY 0.13 K.C.F. | | TOTAL WEIGHT | HEAD AT LEFT OF SLICE | LATERAL THRUST ON LEFT SIDE | NET UNBALANCED FORCE | | SUBMERGED BASE LENGTH | MEAN HYDROSTATIC HEAD | NORMAL UPLIFT FORCE | NORMAL EFFECTIVE FORCE | tan φ | RESISTING FORCE | ARC LENGTH | RESISTING FORCE | DRIVING | RESISTING |
| n | VOL. FT.³ | WT. KIPS | VOL. FT.³ | WT. KIPS | W KIPS | H FT. | P | Q KIPS | | b FT. | h FT. | U KIPS | N KIPS | | N tan φ KIPS | L FT. | LC KIPS | +T KIPS | −T KIPS |
| 1 | — | — | 150 | 17 | 17 | 0 | 0 | – | 5 | 20 | 7 | 9 | 9 | 0.9 | 8 | — | — | 2 | — |
| 2 | — | — | 520 | 60 | 68 | 12 | 5 | – | 15 | 26 | 17 | 27 | 40 | 0.9 | 36 | — | — | 15 | — |
| 3 | — | — | 760 | 101 | 101 | 25 | 20 | – | 6 | 27 | 25 | 42 | 56 | 0.9 | 51 | — | — | 30 | — |
| 4 | 150 | 16 | 725 | 93 | 109 | 29 | 36 | 8 | – | 28 | 27 | 47 | 55 | 0.9 | 50 | — | — | 38 | — |
| 5 | 262 | 27 | 456 | 59 | 86 | 24 | 18 | 12 | – | 25 | 19 | 33 | 43 | 0.9 | 39 | — | — | 45 | — |
| 6 | 200 | 22 | 119 | 15 | 37 | 14 | 6 | 6 | – | 26 | 7 | 11 | 18 | 0.9 | 16 | — | — | 25 | — |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| TOTALS | | | | | | | | | | | | | | | 200 | | 0 | 151 | 0 |

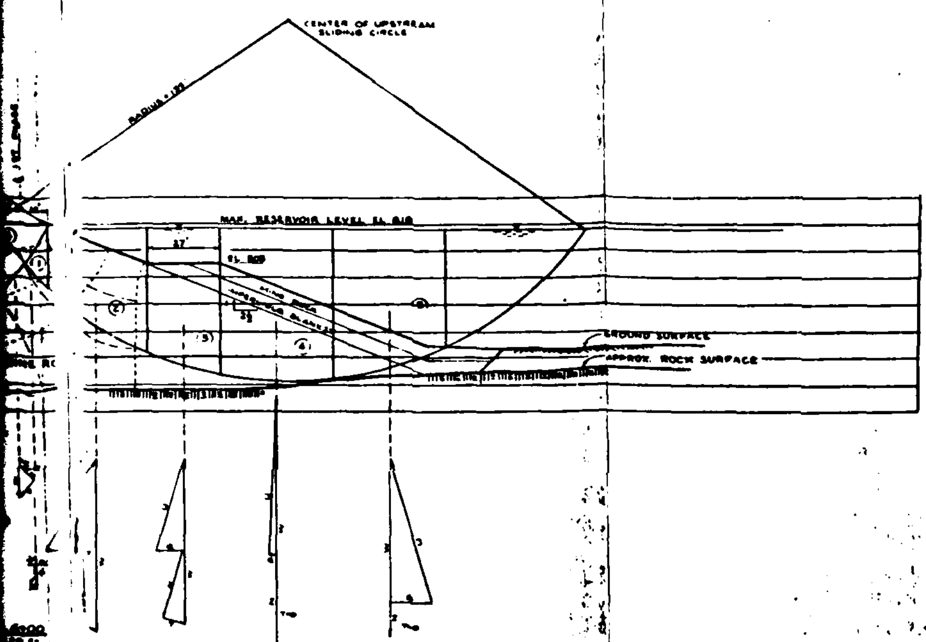
| RESULTS | | | |
|---|---|---|---|
| FORCES | | | FACTOR OF SAFETY |
| RESISTING | | DRIVING | |
| ΣN tan φ | ΣLC | ΣT | (ΣN tan φ + ΣLC) / ΣT |
| 200 | — | 151 | 1.32 |

| BASIC DATA | | | |
|---|---|---|---|
| MATERIAL | DENSITIES | | ANGLE OF INTERNAL FRICTION |
| | DRAINED K.C.F. | SAT'D. K.C.F. | DEG. |
| MINE ROCK (M.R.) | 0.11 | 0.13 | 42° |
| | | | |
| | | | |

UPSTREAM SLOPE STABILI

| SLICE NO | WEIGHTS | | | | | LATERAL HYDROSTATIC FORCE | | | | HYDROS UPLIF | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DENSITY 0.13 K.C.F. | | DENSITY K.C.F. | | TOTAL WEIGHT | HEAD AT LEFT OF SLICE | LATERAL THRUST ON LEFT SIDE | NET UNBALANCED FORCE | | SUBMERGED BASE LENGTH | |
| n | VOL. FT.³ | WT. KIPS | VOL. FT.³ | WT. KIPS | W KIPS | H FT. | P | Q KIPS | | b FT. | h F |
| 1 | 240 | 31 | — | — | 31 | 0 | 0 | – | 18 | 19 | 9 |
| 2 | 1140 | 148 | 208 | 13 | 161 | 24 | 18 | – | 30 | 45 | 35 |
| 3 | 1035 | 135 | 351 | 22 | 155 | 46 | 66 | – | 25 | 28 | 51 |
| 4 | 1480 | 192 | 860 | 54 | 246 | 54 | 91 | – | 7 | 42 | 55 |
| 5 | 535 | 69 | 1560 | 97 | 166 | 56 | 98 | 38 | – | 44 | 55 |
| | | | | | | 44 | 60 | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| TOTALS | | | | | | | | | | | |

| RESULTS | | |
|---|---|---|
| FORCES | | |
| RESISTING | | DRIVING |
| ΣN tan φ | ΣLC | ΣT |
| 261 | - | 74 |




## UPSTREAM SLOPE STABILITY ANALYSIS

| SLICE NO. n | WEIGHTS: DENSITY 615 K.C.F. VOL. FT.³ | WT. KIPS | DENSITY VOL. FT.³ | WT. KIPS | TOTAL WEIGHT W KIPS | LATERAL HYDROSTATIC FORCE: HEAD OF WATER AT LEFT OF SLICE H FT. | LATERAL THRUST ON LEFT SIDE P | NET UNBALANCED FORCE Q KIPS | HYDROSTATIC UPLIFT: SUBMERGED BASE LENGTH b FT. | MEAN HYDROSTATIC HEAD h FT. | NORMAL UPLIFT FORCE U KIPS | FRICTIONAL RESISTANCE: NORMAL EFFECTIVE FORCE N KIPS | tan φ | RESISTING FORCE N tan φ KIPS | COHESION RESISTANCE: ARC LENGTH L FT. | RESISTING FORCE LC KIPS | TANGENTIAL WEIGHT COMPONENTS: DRIVING +T KIPS | RESISTING −T KIPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 240 | 31 | — | — | 31 | 0 | 0 | – 18 | 19 | 9 | 11 | 23 | 0.9 | 21 | — | — | 9 | — |
| 2 | 1140 | 148 | 208 | 13 | 161 | 24 | 18 | – 40 | 45 | 36 | 101 | 60 | 0.9 | 54 | — | — | 44 | — |
| 3 | 1025 | 133 | 351 | 22 | 155 | 46 | 66 | – 25 | 28 | 51 | 89 | 65 | 0.9 | 58 | — | — | 21 | — |
| 4 | 1480 | 192 | 860 | 54 | 246 | 54 | 91 | – 7 | 42 | 57 | 150 | 99 | 0.9 | 89 | — | — | 0 | — |
| 5 | 535 | 69 | 1560 | 97 | 166 | 56 | 98 | 38 – | 44 | 51 | 140 | 32 | 0.9 | 29 | — | — | 0 | — |
| | | | | | | 44 | 60 | | | | | | | | | | | |
| TOTALS | | | | | | | | | | | | 279 | | 251 | | 0 | 74 | 0 |

| RESULTS | | | |
|---|---|---|---|
| FORCES | | | FACTOR OF SAFETY |
| RESISTING | | DRIVING | |
| ΣN tan φ | ΣLC | ΣT | (ΣN tan φ + ΣLC) / ΣT |
| 251 | - | 74 | 3.39 |

E. D'APPOLONIA ASSOCIATES

DWG NO 1423

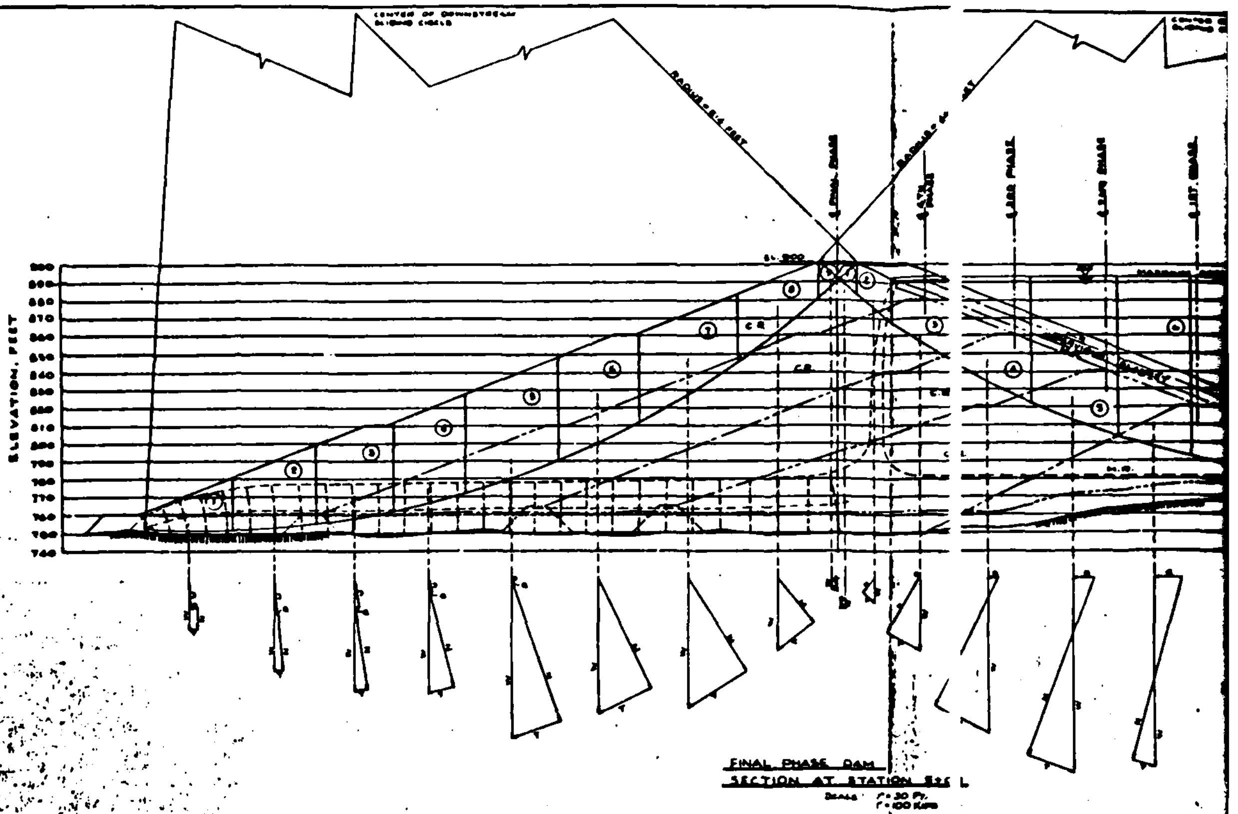
| NO | REFERENCES |
|---|---|

REVISIONS

PEA RIDGE TAILINGS DAM-STABILITY ANALYSIS FIRST PHASE

PEA RIDGE MINE
WASHINGTON COUNTY, MISSOURI

MERAMEC MINING CO.




FINAL PHASE DAM
SECTION AT STATION 52+L

SCALE: 1" = 30 FT.
1" = 100 KIPS

DOWNSTREAM SLOPE STABILITY ANALYSIS

| SLICE NO. | WEIGHTS: DENSITY 0.10 K.C.F. VOL. (CU. FT.) | DENSITY 0.10 K.C.F. WT. (KIPS) | DENSITY 0.11 K.C.F. VOL. (CU. FT.) | DENSITY 0.11 K.C.F. WT. (KIPS) | TOTAL WEIGHT W (KIPS) | LATERAL HYDROSTATIC FORCE: HEAD CAUSING UPLIFT H (FT.) | LATERAL THRUST P | NET UNBALANCED FORCE Q (KIPS) | | HYDROSTATIC UPLIFT: SUBMERGED BASE LENGTH b (FT.) | MEAN HYDROSTATIC HEAD h (FT.) | NORMAL UPLIFT FORCE U (KIPS) | FRICTIONAL RESISTANCE: NORMAL EFFECTIVE FORCE N (KIPS) | tan φ | RESISTING FORCE N tan φ (KIPS) | COHESION RESISTANCE: ARC LENGTH L (FT.) | RESISTING FORCE LC (KIPS) | TANGENTIAL WEIGHT COMPONENTS: DRIVING +T (KIPS) | RESISTING −T (KIPS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 140 | 16 | 300 | 79 | 95 | 5 | 2 | – | 13 | 49 | 17 | 52 | 40 | 0.7 | 28 | — | — | 15 | — |
| 2 | 440 | 46 | 1000 | 113 | 172 | 52 | 15 | – | 1 | 46 | 24 | 69 | 100 | 0.7 | 70 | — | — | 18 | — |
| 3 | 1105 | 116 | 580 | 91 | 207 | 23 | 16 | 8 | – | 44 | 19 | 52 | 184 | 0.7 | 108 | — | — | 28 | — |
| 4 | 1640 | 156 | 460 | 91 | 318 | 16 | 8 | 6 | – | 41 | 10 | 36 | 182 | 0.7 | 127 | — | — | 60 | — |
| 5 | [illegible] | [illegible] | 70 | 8 | 696 | 7 | 2 | 2 | – | 20 | 4 | 5 | 274 | 0.7 | 192 | — | — | 94 | — |
| 6 | [illegible] | [illegible] | — | — | 250 | — | — | – | – | — | — | — | 226 | 0.7 | 158 | — | — | 108 | — |
| 7 | 2400 | [illegible] | — | — | 240 | — | — | – | – | — | — | — | 201 | 0.7 | 141 | — | — | 128 | — |
| 8 | 1500 | [illegible] | — | — | 158 | — | — | – | – | — | — | — | 108 | 0.7 | 74 | — | — | 82 | — |
| 9 | 210 | 21 | — | — | 21 | — | — | – | – | — | — | — | 15 | 0.7 | 10 | — | — | 15 | — |
| | | | | | | | | | | | | | | | 908 | | | 535 | |

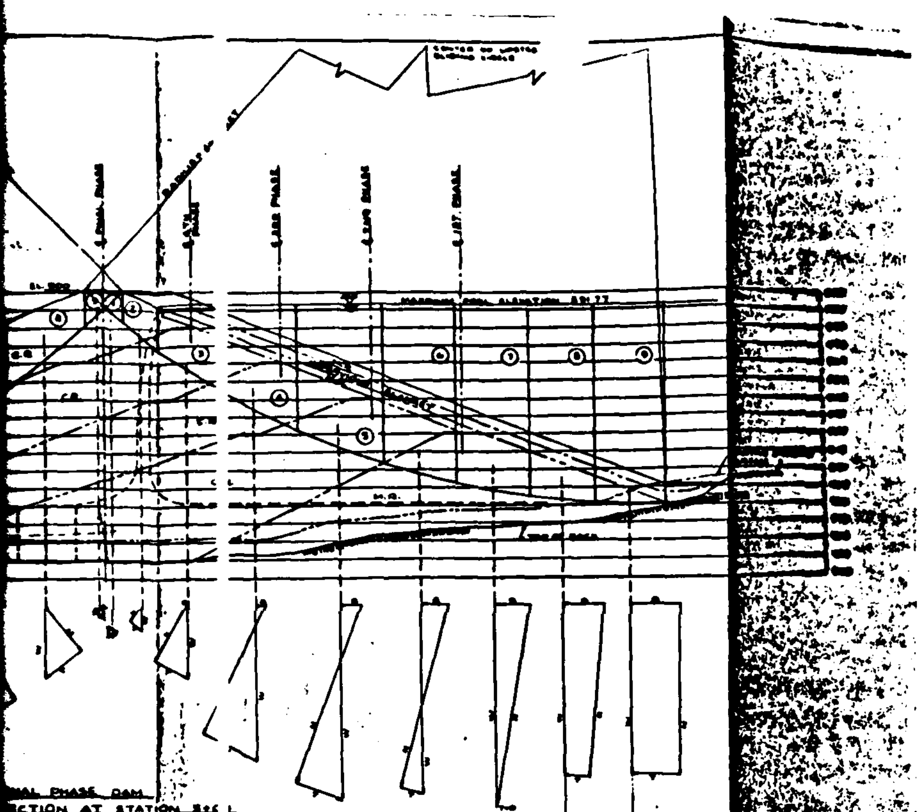
| RESULTS: FORCES RESISTING ΣN tan φ | ΣLC | DRIVING ΣT | FACTOR OF SAFETY |
|---|---|---|---|
| 908 | — | 535 | 1.70 |

| BASIC DATA: MATERIAL | DENSITIES: DRAINED (K.C.F.) | SATURATED (K.C.F.) | ANGLE OF INTERNAL FRICTION φ (DEG.) | COHESION C (K.S.F.) |
|---|---|---|---|---|
| COBBER REJECT (C.R.) | 0.10 | 0.11 | 35° | — |
| MINE ROCK (M.R.) | 0.11 | 0.13 | 42° | — |

UPSTREAM

| SLICE NO. | WEIGHTS: DENSITY 0.10 K.C.F. VOL. (CU. FT.) | WT. (KIPS) | DENSITY 0.11 K.C.F. VOL. (CU. FT.) | WT. (KIPS) | DENSITY 0.13 K.C.F. VOL. (CU. FT.) | WT. (KIPS) | DENSITY VOL. (CU. FT.) |
|---|---|---|---|---|---|---|---|
| 1 | 180 | 18 | — | — | — | — | — |
| 2 | 440 | 44 | — | — | — | — | — |
| 3 | — | — | 810 | 89 | 330 | 43 | 66 |
| 4 | — | — | 1450 | 160 | 726 | 95 | 550 |
| 5 | — | — | 1600 | 176 | 753 | 98 | 1410 |
| 6 | — | — | 680 | 75 | 1360 | 161 | 1880 |
| 7 | — | — | — | — | 1660 | 216 | 2300 |
| 8 | — | — | — | — | 1110 | 144 | 2020 |
| 9 | — | — | — | — | 702 | 91 | 2640 |
| | | | | | | | |

...COUNT TO TOP OF IMPERVIOUS BLANKET




...AL PHASE DAM
...CTION AT STATION 8+6 L
SCALE: 1"=30 FT. 1"=100 KIPS

...S DATA

| | Densities | | Angle of internal friction φ | Cohesion c |
|---|---|---|---|---|
| | [illegible] | Saturated | | |
| | K.S.F. | K.S.F. | DEG. | K.S.F. |
| | 0.10 | 0.11 | 35° | — |
| | 0.11 | 0.13 | 45° | — |

## UPSTREAM SLOPE STABILITY ANALYSIS

| Slice | Weights: Density 0.10 K.C.F. Vol. (Cu. Ft.) | Wt. (Kips) | Density 0.11 K.C.F. Vol. (Cu. Ft.) | Wt. (Kips) | Density 0.13 K.C.F. Vol. (Cu. Ft.) | Wt. (Kips) | Density [illegible] K.C.F. Vol. (Cu. Ft.) | Wt. (Kips) | Total Weight W (Kips) | Lateral Hydrostatic Force: Head at left of slice H' (Ft.) | Lateral thrust on left side P | Net unbalanced force Q (Kips) | | Friction Resistance: Normal effective force N (Kips) | Tan φ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 180 | 18 | — | — | — | — | — | — | 18 | — | — | — | — | 14 | 0.7 |
| 2 | 440 | 44 | — | — | — | — | — | — | 44 | — | — | — | — | 34 | 0.7 |
| 3 | — | — | 810 | 89 | 330 | 43 | 66 | 4 | 136 | 0 | 0 | — | 2 | 117 | 0.7 |
| 4 | — | — | 1450 | 160 | 736 | 96 | 550 | 33 | 289 | 7 | 2 | — | 10 | 264 | 0.7 |
| 5 | — | — | 1600 | 176 | 733 | 96 | 1410 | 88 | 362 | 26 | 21 | — | 39 | 331 | 0.7 |
| 6 | — | — | 680 | 75 | 1240 | 161 | 1880 | 117 | 353 | 44 | 60 | — | 63 | 388 | 0.9 |
| 7 | — | — | — | — | 1660 | 216 | 2580 | 161 | 377 | 60 | 112 | — | 68 | 380 | 0.9 |
| 8 | — | — | — | — | 1110 | 144 | 2820 | 176 | 320 | 76 | 180 | — | 78 | 322 | 0.9 |
| 9 | — | — | — | — | 702 | 91 | 3640 | 226 | 317 | 91 | 258 | — | 92 | 319 | 0.9 |
| | | | | | | | | | | 106 | 350 | | | | |

...COUNT TO TOP OF IMPERVIOUS BLANKET

RESULTS
FORCES
RESISTING

E. D'APPOLONIA ASSOCIATES
CONSULTING ENGINEERS
PITTSBURGH PA.
CONT. NO. 61-100 DWG. NO. M27